
THE
NATURAL HISTORY
OF THE
MINERAL KINGDOM.

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IN THREE PARTS.

PART I.

Of the Natural History of the Strata of Coal, and of the Concomitant Strata.

PART II.

Of the Natural History of Mineral Veins, and other Beds and Repositories of the precious and useful Metals.

PART III.

Of the Natural History of the Prevailing Strata, and of the principal and most interesting Phenomena upon and within the surface of our Globe.

By JOHN WILLIAMS, *Mineral Surveyor, F. S. S. A.*

IN TWO VOLUMES.

VOL. I.

EDINBURGH:
PRINTED FOR THE AUTHOR,
BY THOMAS RUDDIMAN.

1789.

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Jos. Banks

DEDICATION.

TO
ROBERT BAIRD
OF
NEWBYTH
ESQ.

SIR,

I BEG leave to present to you my History of the Mineral Kingdom, a work which is intended to facilitate the researches of those who are employed in exploring those dark regions of nature, which contain treasures for the comfort of the public at large, and the emolument of each individual to whom they belong.

You,

You, Sir, are interested in the success of every scheme which tends to promote this great design ; and, therefore, with the greater freedom I venture to inscribe to you the result of my enquiries.

The undertaking is difficult, the subject is dark, and the road has been explored by few. It will be allowed that my intention is good, in endeavouring to assist gentlemen to obtain possession of those treasures of nature, and in the best and easiest manner to draw them from their subterraneous abode.

I cannot venture to say how far I have succeeded in the execution of my design. My intention is not so much to propose or establish new theories, as to elucidate the subject, by conclusions drawn from fact and experience ; and every one must allow these are our surest guides in science and in art. I pretend not to instruct the philosopher, but he may be amused, by having such operations of nature delineated to him as he never had an opportunity in
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person to investigate. May I hope that my labours will prove useful to landed gentlemen, in directing their future proceedings in Mineralogy? From your connection with the subject, and your enlarged views concerning it, you are justly sensible of its advantages to society. I request you will take it under your protection, and allow me, with the greatest respect, to subscribe myself,

S I R,

Your much obliged and

Most obedient humble servant,

JOHN WILLIAMS.

GILMERTON, }
September 1789. }

PREFACE.

GREAT BRITAIN has long ago been called a fortunate island, and it must be acknowledged, that the appellation is as proper to Britain as to any other island or country in the world. The soil of this island is adapted to produce excellent grain and fruits. Her downs and verdant hills are covered with store of the best of sheep, which yield excellent fleeces for our manufactures, as well as food for our tables. Numerous herds of beeves are fed upon her mountains and in her meadows, and her seas and rivers abound in the most delicious fish. The climate of this island is mild and healthy; her mountains breathe the purest air, and abound in the sweetest springs, and her valleys are washed and fertilized by pure and limpid streams.

This fortunate island is placed almost in the center of the habitable world, with free and ready egress to the Mediterranean, the Baltic, the East and West Indies, and all other seas to the south and north;—the most convenient situation for extensive commerce, which is greatly facilitated by
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the safety and prodigious extent of her sea coasts, the depth and numbers of her rivers, and the depth and numbers of her bays and sinuses all round the island.— Her forests produce the hardiest oaks for ship-building, and her sea-ports the best and hardiest sailors, who are in a manner bred upon the water; and no island in the world ever yet arrived at such commercial eminence, and, in consequence, at such a height of power, wealth, and grandeur.

But it is not all the external productions of this island put together, favoured as she is by the goodness of her soil and situation, and assisted by the excellence of her constitution, and the utmost exertion of the genius of her sons, that ever was, or ever will be able to raise her to such a height of power and wealth, or to such commercial and political consequence in the world. The soil of some other countries is as good as that of Britain. The island of Sicily produces as excellent grain and better fruits, and some parts of Spain as good, if not better fleeces. But Britain has other valuable sources of commerce and wealth. The materials of many of the various and extensive

tenfive manufactures of the island, are derived from the bowels of the earth, from her plentiful mines and coal-works.

This is the source of the materials of our most numerous and extensive manufactures, and of the utensils of them all; and it is our manufactures that fill and extend the channels of commerce, and bring home our wealth from afar.

This island is a nursery of arts, as well as of manufactures and commerce.

It is a curious and entertaining amusement to reflect upon the connection and dependence of the arts upon one another, and upon the improvements and advances of society in a polished commercial country. A man of genius and of judgment, equal to the task, with a stock of information and scope of thought like Raynal, who would write a book to shew us the progress and improvements of the useful arts, the æra of remarkable discoveries and their effects, and the influence which the improvements of the useful arts has upon the commercial and political state of the nation, and of the world in general, would deserve the thanks of his country for the
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extensive information, useful instruction, and national entertainment which his book would afford.

Perhaps it would then appear, that the great quantity and variety of metal which this island produces has more influence upon the commerce, wealth, and power of the nation than we are accustomed to imagine at present. But as I have neither abilities nor materials for such enquiries, I will leave them to be investigated by such as are equal to the task. This much, however, appears very obvious to me, that great numbers are profitably employed in our mines, and in conveying the metals out of the nation; that the value of these metals, whether raw or manufactured, is all clear gain to the nation; that still greater numbers are employed to work upon the metals for all useful and ornamental commodities, and for all utensils, trades, and arts. What is done without the metals? Look into the kitchens and buffets of the great and wealthy: what profusion! And yet all for use. When we pass thro' Cheapside in London, one might imagine that all the metal of the world was furnished

bished up and arranged there for his inspection ; and yet it is in some proportion equally plentiful every where. The utility of the metals is analogous to their abundance. The mathematical instrument maker does but little without them, and much is used by the blacksmith, whitesmith, coppersmith, pewterer, tin-plate worker, coachmaker, cabinet-maker, clockmaker, silversmith, engraver, printer, &c. The quantities used by the various sorts of founders, and the plumbers, are immense. But if you would wish to have a full and comprehensive view of the profusion and great utility of the metals, step into the work-shops and ware-houses of Birmingham : How many thousands are there at work ! What amazing quantities of wrought goods are stored there ready for exportation and home consumption ! There you will see them busied in making all that is worn of metal by the lady and her maid, the clown and the beau, the horse and his rider, both for ornament and real use ; and their ware-houses contain enough for half the world, which must pass through the channels of commerce. In short, the plenty

ty and variety of our own metals, and the plenty and excellent quality of our coals, enables us to manufacture and export more and greater variety of metallic goods than any other nation whatever.

From this imperfect sketch of the profusion and extensive use of our metals, I would infer the great importance of the British mines to the commerce, wealth, and grandeur of the nation; and I would likewise infer the importance of improvements in the natural history of the mineral kingdom in such a country, especially at this period.

Mineralogy is now become a fashionable study in most countries of Europe, and many useful and entertaining discourses have been made of late years. But the present vogue and reputation of this branch of knowledge is nothing in comparison of its great utility. There cannot be a more interesting study for a Briton; for while we have extensive mines and collieries, and while the production of them can be obtained at a moderate expence, we shall be considerable as a manufacturing and a commercial people.

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It is a particular loss to the increase of knowledge in the natural history of the mineral kingdom, that this branch of science is neglected in our public schools. Mineralogy is taught in the Universities abroad. I believe, that what may be called fossilogy, or the arrangement and description of mineral fossils, is taught in some of our public schools ; but their instructions are founded upon small detached samples, the collections of the cabinet, which leave the country gentleman and the young miner as much in the dark as before, with respect to the knowledge of nature and of real mineral appearances, which are the true sources of useful knowledge in these matters ; and this species of knowledge is of great importance. No country in the world depends so much upon the productions of the mineral kingdom, for the means of comfortable accommodation, wealth, and power, as the island of Britain.

Coal is now become of such immense consequence to our cities and populous counties, to our forges and other manufactures, that it was impossible for us to have arrived at such commercial eminence,

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and it is as much impossible for us to support our present flourishing state of society without it; and we are equally indebted to the other parts of the mineral kingdom for many of the staple commodities, which are so widely diffused in the numerous channels of our extensive commerce.

When we consider that many thousands, I may say millions, of industrious hands are employed one way or other about the produce of the mineral kingdom in this island, we are convinced of the importance of the increase of knowledge in Mineralogy, and of the advantage that would accrue to the nation from the institution of a class for teaching this science at our public schools.

It may be said, that the necessary aids for such an institution are wanting in this island;—there has not yet appeared any genuine natural history of the mineral kingdom, founded on such sound principles of philosophy, as would enable a teacher to lay the foundation of, and to complete a continued course of instructions in the science of mineralogy. There are not, that I know of, many valuable books upon
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the subject in our language, excepting such as treat of chemistry or metallurgy, and such as arrange and describe fossil bodies, as they are found in the cabinets of the curious,—almost all the rest is nothing but wild theory and system, built upon fanciful notions and opinions, the fruits of the closet, which have no foundation in the truth of facts, as they appear in natural history; and therefore such books can be of no use but to amuse, to multiply diversity of opinions, and to increase ignorance of the real knowledge of nature.

It is this consideration which induces me to give to the public a work the fruit of more than forty years experience and observation, to which great opportunities and a mind ardent in researches of this nature prompted me. How I have executed my plan, the Public shall judge: But I flatter myself, from the great number of facts I have ascertained, and from the many discoveries I have made, that my observations may be productive of real use to mankind, by exciting the pursuit of, and giving a proper direction to the study of this science, with more pleasure, ease, and

and proficiency than hitherto. The knowledge of truth in every branch of science is pleasant and profitable; and it is generally acknowledged, that natural history is the most pleasant and profitable of all human studies and researches; and of all the parts of natural history, the mineral kingdom is the most magnificent and august, provided that we study nature herself. There is a noble air of grandeur and magnificence in the sections of lofty piles of strata, in huge rugged rocks, and hanging precipices, in profound caverns, and high and extensive cliffs of the sea, not to be found in other objects around us.—These scenes astonish and captivate the mind at first sight; and the better we are acquainted with them, the more we are enraptured with the view of the wonderful and endless variety which we discover in these scenes of nature; and habitual application to these researches assimilate the mind by degrees to the greatness of the subject. Discoveries of truth and attainments of knowledge in these researches have the happiest effect on the human mind. In pursuing these studies successfully, the
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mind is elevated, the understanding is enlarged and filled with great ideas, and all the powers of the soul are exalted and pleased at being able to comprehend somewhat of these great works of God. In short, I conclude that there are no human studies so amusing, so entertaining, and delightful as these, when the student delights in the sequestered scenes of nature. There is such a dignity and variety in every part of this subject, that it is impossible for a person of any genius and taste to be cloyed with these pursuits. Who can possibly weary of endless change, and all either astonishingly great, or fantastically grotesque, or beautifully regular; and I know well, that the more we improve in the knowledge of these natural scenes, the more we delight in them; and therefore, without being a prophet, I will venture to predict, that whenever young gentlemen of genius and attention take pleasure in these researches, it may be then proclaimed, that the darkness is past, and that the glorious light of science is rising upon the mineral horizon. Great and rapid progress will then be made in this branch of
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natural knowledge, and the mineral kingdom will soon be understood as well as the animal and vegetable kingdoms. But the importance of these studies should be preferred to the pleasure of them in this mining, manufacturing, and commercial country, where it may be supposed there are but few landed estates that do not contain some mine or mineral fossil or other, which may contribute to the public good, and to private emolument; and, therefore, I wish to excite a lively sense of the importance of increasing mineral knowledge.

In such a country as this, young gentlemen of landed property should be initiated in the principles of Mineralogy, and such youth as aim at professional abilities in mineral lines of business, should have it in their power to lay an early foundation of knowledge in this branch of natural history, which is the best way to arrive at eminence in the stations they are intended to fill.

I have, in the following sheets, contributed a small moiety towards the acquisition of knowledge in mineral science.

I have treated pretty fully of the natural history of the strata of Coal, and of such other strata as are found to accompany coal; I have treated fully and distinctly of the appearances, indications, and symptoms of coal; and I have been very careful to distinguish the real and certain appearances from such as are either false or doubtful. In this part of my subject I have taken due pains to investigate and explain every thing that I thought would throw light upon and communicate useful information relating to a subject of so much importance to society; and I am persuaded that my treatise upon coal will be of use to landed gentlemen, towards facilitating the progress of youth in the knowledge of this branch of natural history, and as an index for the young coal-master.

The second subject treated of in this work is the Natural History of Mineral Veins, and of the other beds and repositories of the precious and useful metals. I did not at first intend to publish my treatise concerning metallic mines at this time, because, it is not completed; but
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when the first part of my work was put in the press, I reflected that this second part contains a number of particulars which may be useful to landed gentlemen and young miners; and as it is very uncertain whether I shall proceed any farther in these mineral essays than the two volumes now published, I thought it was better to offer this in its present imperfect state than to suppress it altogether.

The history and description of mineral veins is perhaps more full and explicit than can be found any where else. The precepts upon shodding and hushing are the result of much practice: The observations and instructions concerning the appearances and symptoms of mines will give satisfaction, and be a sure guide to all such as have occasion to consult them; and the local examples of the appearances of some valuable mines may, in the course of time, be of great use to society.

Such historical facts have always been considered as valuable communications. In short, all that is advanced in this imperfect

perfect fragment is the fruit of my own observation and experience; and, therefore, it should be of some value, such productions being generally useful to society.

These two essays upon coal and the metallic mines compose the first volume.

In the second volume I proceed to take a view of the prevailing strata of Great Britain, and of many interesting phenomena of the superficies of our globe.

The philosophy or natural history of the superficies of the globe is an interesting subject to all mankind in a social state.

Many of the necessaries, and most of the conveniencies of life are found either upon or a little within the surface of the globe, being the productions of the mineral kingdom; and we are obliged to many of the strata for the plenty and excellence of our food. Lime is of great use to meliorate the soil, and to stimulate or excite vegetation, and the gradual weathering and decomposition of the superficies of many other strata, restore and increase the soil, which may be in part exhausted or carried away by rains and currents; and if we look

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upon our houses, and within them, we may soon perceive how much we are indebted to the mineral kingdom.

The most remarkable phænomena which present themselves to us upon the surface, and as far as we penetrate within the surface of the globe, are remarked and explained in this third part under several heads.

1st, I have taken a view of the prevailing rocks and strata of this island, to see which of them are stratified, and which of them are not. On this head I have examined the appearance, colours, quality, thickness, regularity, bearing, slope, and course of the several classes of strata: I have collected a great number of interesting facts and local examples; and I have been at great pains to select, and to examine particularly such strata as are most useful to society.

2^d, I have treated of the stratification of the superficies of our globe by the agency of water. In this disquisition the enlightened and candid naturalist will find a considerable number of abstruse, but interesting phænomena above ground and below,

low, raised from obscurity, and treated of and explained upon rational principles, in a clear, convincing, and satisfactory manner.

3^d, I have examined part of the modern system of Count Buffon and others upon this subject, to see how they correspond with the real structure of the superficies of the globe, and other phenomena of nature; and what I have advanced under this head will bear the severest scrutiny by every test.

4th, I have treated of the natural history of mountains, and of their glens and excavations, which is a sublime and difficult subject. In this part the height and figure of the mountains, the profundity, direction, and extent of their excavations, the exterior and interior structure, with all the most remarkable phenomena of mountains, and other irregularities of the surface of the globe, are fully accounted for and explained to a demonstration, upon the principles of the agency of water, and of the prodigious height and force of the diluvian tides; and the clear light which is thrown upon this great subject, will

will convince every candid naturalist of the truth of my propositions.

5th, I have examined the nature, or quality, the size, figure, and other phenomena of the larger grains and fragments which are found in the composition of our rocks and strata, and these enquiries naturally lead us into profound and interesting disquisitions relating to the universal deluge, —to the present and the antediluvian earth.

This profound and awful subject is naturally mysterious and obscure, but it has been involved in infinitely greater obscurity and confusion by the theories and systems of all ages, as the subject never has been well understood ;—out of which obscurity and confusion I have endeavoured to raise it, and to explain and illustrate the doctrine of the deluge upon rational principles, agreeable to the laws and phenomena of nature.

6th, I have made a few observations concerning several other subjects relating to the mineral kingdom, among which there will be found an interesting treatise of Volcanoes.

I beg leave in this place to observe, that in all this work I aim at being useful to society, especially within the limits of my own country,—my native island; but in the tract upon volcanoes my genius and imagination soars above the height of the British mountains, and takes a view of all mankind upon the whole face of the globe, and especially where they now are, or may hereafter be plagued with the dreadful calamity of volcanoes; and to be the instrument of saving many lives from sudden destruction,—to mitigate the miseries and abridge common losses in volcanic countries; and if my rules and instructions for that purpose are thoroughly considered and followed, I am persuaded that what I have written will produce happy effects. The tract upon volcanoes is founded upon experimental science and real knowledge of natural history; and, therefore, I hope, that in time very happy consequences will result from my essay upon this subject; in composing which, the whole powers of my soul were animated and exerted in fervent desires of doing good.

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The dissertations concerning the balance of the waters of the ocean, and the accumulated mountains of ice and frozen snow, which mutually and reciprocally depend upon and illustrate one another; concerning the peopling of America by land from the north-east of Asia, and its being stocked with land animals from Armenia, in an early age, before the mountains of frozen snow were greatly accumulated;—concerning the pestilential effects of humid vapours arising from the slime of new formed lands, from marshes and extensive woods in warm countries, and how to mitigate these dismal calamities, and to banish these undermining enemies of the human race;—concerning the deepening and improving the beds and bars of the navigable and other rivers of the world, and the draining and improving of marshes, new formed, and wood-lands, with the great and glorious consequences of such works, for the health, longevity, general happiness, and prosperity of all nations; are humbly submitted to the examination and censure of such candid and benevolent philosophers as make advances in useful

ful improvements, and the prosperity and happiness of mankind the ultimate end of the exertion of their talents. In these dissertations they will find many valuable hints, which they can improve, and a great deal of matter of vast importance and consequence to the health and welfare of the world, very ill put together, and in an uncouth dress, but which they may arrange, improve, and clothe in better language.

Since writing the above, and all I proposed to advance at present in the following essays, I have perused a New Theory of the Earth, by James Hutton, M. D. F. R. S. Edinburgh, concerning which I beg leave to make a few remarks in this place.

Dr Hutton is a naturalist of eminent abilities, whose knowledge in several branches of mineralogy does honour to his country, as some of his observations in the treatise under review clearly evince. The propositions he states, with the conclusions he draws from them, to confirm his hypothesis in the theory of the earth, shall be the subject of the following observations.

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The Doctor's general system in his theory of the earth may be comprised in these four propositions.

1st, That all our rocks and strata have been formed by subsidence under the waters of a former ocean, from the decay of, and waste of a former earth, carried down to the sea by land-floods.

2^d, That these submarine rocks and strata were heated to the degree of fusion by subterraneous fire, while immersed under the waters of the ocean, by which heat and fusion, the lax and porous sediment was consolidated, perfectly cemented, and all the pores and cavities filled up by the melted matter, while the whole mass was in a state of fusion.

3^d, That the rocks and strata, so formed and consolidated under the waters of the ocean, were afterwards inflated and forced up from under water by the expansive power of the subterraneous fire, to the height of our habitable earth, and of the loftiest mountains upon the surface of the globe.

4th, That these operations of nature, viz. the decay and waste of the old land, the

the forming and consolidation of new land under the waters of the ocean, and the change of the strata now forming under water to future dry land, is a progressive work of nature, which always did, and always will go on in a perpetual succession, forming world after world.

I. The first of these propositions has been fully answered and refuted before it was written, at least before it was published, in my examination of the system of Count Buffon in his Theory of the Earth, which will be found in the second Volume of my Essays upon the Mineral Kingdoms, concerning which, I will venture to say, and the candid intelligent naturalist will say with me, that I have not left the Doctor so much as a particle of earthy matter to form one of his future worlds, for a single particle would save the whole succession. I have now effectually cut off all his supplies, and appropriated them to a better use; and I hope it will be acknowledged, that I have made a good use of them. There is little or no difference between Count Buffon and Dr Hutton in

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this part of their several theories; and therefore, what I have advanced concerning Buffon's, is equally applicable to the Doctor's.

I have, in my examination of Count Buffon's Theory, frankly acknowledged the truth of almost all that the Count and the Doctor advance about the weathering, decomposition, and waste of the superficies of many of our rocks and strata, and of our mountains and cavernous shores.

The spoils of the mountains are carried down by land-floods to the valleys and to the borders of the ocean. So far we go together; but here we must part, as I positively deny that any strata are formed under the waters of the ocean. I have, in that part of my essays, made it evident to a demonstration, that the sea purges itself by the tides of all the earthy matter carried down by the floods, which earthy matter is thrown back upon the shores, in the bays and creeks, and at the mouths of great rivers, where, by degrees, it enlarges the bounds of the dry land in exact proportion to the quantity carried down by the floods.

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In that part of my essays, I have clearly demonstrated, that the earthy matter washed off the face of our mountains and rocks has no manner of tendency to the real waste and destruction of the present earth ; so far from it, that, on the contrary, the habitable parts of the earth are gradually, but really and effectually renovated, enlarged, and improved thereby. I have proved, that many lakes, marshes, and frightful gulphs among the mountains and in the plains, have been filled up in the course of the rivers of the world, which are now rich, beautiful and habitable countries ; that many millions of acres of new land have been made in the valleys and plains, at the mouths of the rivers in the bays, creeks, and shores of the ocean ; and that very many and extensive portions of this new land are now the fat valleys by the rivers, which are the scenes of population, wealth, and social happiness. It is upon this description of land that the highest number of the great commercial cities of the world are seated, such as, for instance, London, Amsterdam, Alexandria, and many of the cities of China, &c. which
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have long been the seats of learning and the arts, of commerce, wealth, and glory.

Whoever will take the trouble to peruse my essays, will be convinced and satisfied that the Deltas, Belgias, and Carfes, and other descriptions of new land, formed and forming in all parts of the world, fully and perfectly correspond with the quantity of matter washed off the mountains and rocks, and they will there see it clearly proved that all this is a real, a great, a substantial, and a durable improvement of the present earth. Man cannot live upon the summits, nor high up the sides of lofty mountains; but the frosts and thaws, and other changes of the air and weather, decompose part of the superficies of the mountains, which is carried down by the floods to the valleys and to the margin of the sea, where new land is gradually increased, which enlarges the bounds of the earth in convenient situations for increased population, and for all the improvements which are necessary for increasing human and social felicity; and are not the spoils of the mountains much better disposed of in this way, than if spread out at random through

through the bounds of the ocean, to form imaginary worlds in the craniums of our modern philosophers?

But this use which the wise and benevolent providence of God makes of the sediment of rivers in the ordinary course of things, is not a well fancied hypothesis, proposed for the amusement or confusion of the inquisitive mind of man; but it is a real and visible fact, which may be viewed, examined, and thoroughly investigated by the man of leisure and abilities; and I am persuaded, that if Dr Hutton will read my papers upon this subject, he will be convinced of the errors of his hypothesis.

Now, it being clearly demonstrated, that no strata are formed in the bed, or under the waters of the ocean, all our author's investigations and reasoning upon that subject of course fall to the ground; and I have in my essays made it evident to a demonstration, that if, for argument's sake, we allow the particles of matter carried down by the rivers to be spread out over the bounds of the ocean, and to subside in it, we should, in that event, have no coal,
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no limestone, freestone, nor any other useful fossil body. We should have no such thing as strata, nor bed, nor division of any kind whatsoever, but all would be one uniform solid mass of sediment, compounded of all things. It is in vain to say it would be otherwise. The known and acknowledged laws of nature forbid it; and all the experience we have of sediment proves the fact, that all would be a blended indistinguishable mass, as I have fully shewn in my essays, to which I refer for clearing up the point under consideration. If we can suppose any order or distinction in sediment, it must agree with the laws of gravitation; of course the heaviest particles would subside, and take possession of the lowest place, from which they would not be dislodged by the lightest. But we need not descend to particulars. Stratification must be performed by a shallow spread and flow of water; but we cannot allow of stratification, nor of any distinction of strata of different qualities under the bed or waters of the ocean, without a miracle for each; and we need not have recourse to miracles, when the phenomena
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of nature can be as well and better explained upon rational and mechanical principles, agreeable to the known laws and visible operations of nature. But I will not insist upon this topic here. I have already confuted this part of the Buffonian theory, and the Huttonian differs but little from it.

II. The second thing proposed to our consideration in Dr Hutton's Theory is, the consolidation of our rocks and strata, while still under the waters of the ocean, by the heat and fusion of subterraneous fire. Our author's doctrine of subterraneous fire, and its effects in the consolidation of the strata, by means of fusion beneath the waters of the ocean, is a singular hypothesis; but it is not altogether new.— Woodward and others have advanced the notions of central and subterraneous fires; and they also pretended to account for many of the phenomena of nature from the operations or effects of these imaginary fires; but I do not know that any of them before our author gave these fires the office of melting the earthy mass, in
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order to cement and consolidate our strata; though Ray conjectures, that mountains might be forced up by earthquakes, and by the flatus of volcanic fire; but none, that I know of, before the Doctor, have given this imaginary central fire the office of melting the oozy bed of the ocean, in order to reduce it by fusion into solid rocks and strata.

Our author's abilities as a naturalist, and his chemical knowledge, enable him to produce and reason upon many seeming facts to support and illustrate his hypothesis; but, unluckily for this proposition, we see in little the very same natural effects produced before our eyes without the application of visible fire, though not without the influence and effects of the elementary atmospherical fire. There is no room to doubt, that natural chemistry is more powerful, extensive, and various than the artificial. It is difficult to limit the powers and effects of variously combined mineral liquors, in dissolving part of various fossil bodies in their natural situations, in the bowels of the earth. One thing we are sure of, that various terrene matters

matters are in a dissolved or fluid state, mixed with the waters which percolate the pores and crannies of our rocks and strata. As an undeniable proof of this, we see numerous fossil bodies of various qualities and degrees of hardness formed and forming before our eyes, which are as well consolidated and cemented as if they had been fused by fire upon our author's plan of cementation; and these, not in small and inconsiderable crystallizations and stalactites, but we see considerably large concretions formed by a gradual accretion of matter deposited by water. In some places, we see caverns of various degrees of extent and magnitude, some of which are almost, and others altogether filled up by a small flow of water, depositing particles of stony matter; and the bodies so formed are afterwards consolidated, in the course of no very long time, to degrees of strength and induration equal to any of our rocks and strata. Mines recently worked are in many places so quickly choaked up by the formation of various concretions, that we are often obliged to demolish them, to pre-

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vent their stopping up the passage altogether.

I have seen subterraneous mines or galleries, which were worked by my direction, so filled up and choaked; and I can shew some others, which, if neglected for ten or a dozen of years, would be choaked up so effectually, and the contents would be so consolidated, that it would require an expence to open them up again, almost if not fully equal to the first. The history or natural philosophy of stony concretions is already explained in the 2d Vol. of my Essays, and need not be repeated here.

We find in many places various kinds of spar, of fluor, and of agate, formed and forming by water, depositing particles of different qualities. Some of the bodies so formed are homogeneous, and some compounded. Some of these concretions assume a fine smooth uniform texture; others exhibit, when broken, a cubic and a tabulated structure; and others again have a coarse and homely grain in the inside. In some places, the quality of these concretions is calcareous, in others siliceous,

aceous, and in many places ferruginous; and we frequently find them containing a mixture of particles of different qualities. Many of these acquire degrees of strength and hardness equal to any of our rocks and strata; and therefore we may infer, that the cementing quality is either contained in the mass of matter deposited by the water, or that it is imparted by the influence of the atmosphere. I am much inclined to believe it is the last, and, I am persuaded, that the elementary fire of our atmosphere inspissates a great many fluid substances in all the three kingdoms of nature; and by penetrating their masses, and being detained and lodged there, brings them gradually to various degrees of solidity, strength, and hardness. Now it is very observable, that the cementing matter which fills up the pores and interstices of our rocks and strata,—which connects their several parts, and promotes their solidity, strength, and induration, has the very same appearance, and is of the very same quality, as the various fossil concretions we are speaking of; but both the stony concretions and the cementing

ting quality of the strata contain a greater variety and mixture of stony matter than we can easily enumerate or describe.

From these observations we may safely infer, that these various substances of different qualities are now in a dissolved fluid state, mixed with water. The various concretions formed by water, issuing into places accessible to the external air, justifies the inference, and proves the truth of it; and that our rocks and strata are cemented and consolidated by similar substances, is evident to our senses; but whether the cementing matter was contained in, and blended with the general composition when the strata were first formed, or was afterwards insinuated by the percolation of water, through the pores and crannies of the strata, I will not now enquire. Some small veins and masses of these substances, found pure in our rocks and strata, seem to favour the supposition of the strata being cemented by the insinuation of particles, and the extraordinary induration of some of our external rocks countenances the same idea; and I have no doubt, that the elementary fire has

a great share in producing every degree of solidity and induration.

Much of the cementing matter of our rocks has more of the appearance of a jelly, which is hardened by degrees from an aqueous solution, than of being produced by the fusion of fire.

These observations and facts make it evident to a demonstration, that fusion by fire is not necessary for the cementing and induration of our rocks and strata. We have abundance of examples in little of a contrary process; and, in truth, the component parts of some of our strata, the inflammable quality of others, and every situation and phenomena of the strata in general, proves, that they have not been affected by fire. We see evident marks of water in the disposition, structure, and form, and in all the exterior and interior phenomena of the strata; but we see no real mark or character of fire, excepting in volcanoes, which are accidental, local, and very limited, have every character of being accidental, and only produce disorder and confusion; and, moreover, the origin and natural history of volcanoes is pretty

pretty well known, and is investigated and explained in the 2d Vol. of my Essays.

The philosopher or naturalist, who can deliberately embrace the idea of our real strata being cemented and consolidated by fusion by fire, either under or out of the waters of the ocean, must have his mind strangely warped by attachment to system. Such a heat as would melt and bring the whole solid globe to a state of fusion, must necessarily heat the whole waters of the ocean up to boiling, and the boiling heat of the waters must continue for many ages. I suppose, that a solid globe of the magnitude and density of our earth, heated to a state of fusion, would require many thousand years to cool again to the temperature of our earth and water; of consequence, the waters would be kept in a boiling state the most of the time: What then would become of all the finny and testaceous tribes of the ocean?

Neither any of them, nor any of their spermatic powers and virtues could possibly live in such a heat; of course, they must be all created anew after each of these worlds is cooled. The terrestrial tribes

tribes must be in as bad a situation as those of the watery element. This appears to be an awkward hypothesis. With respect to the solid part of the globe itself, such a subterraneous heat as would effectually penetrate the whole mass, so as to bring every part to a state of fusion, instead of leaving distinct and regular strata of various qualities, thickness, and other characters, separated from one another, as we find them, the whole solid globe must be run together into one solid slag, which might exhibit many cracks and fractures after cooling; but they would all be the cracks and fractures of an immense mass of glass or slag. There could be no horizontal divisions, nor marks of strata of any kind, nor could we have any coal, nor any useful stone or fossil whatsoever.—Such is the nature of this extraordinary hypothesis?

We have the most early traditions of our globe suffering a great catastrophe and change by water, which is recorded by Moses, and by many other eminent ancient philosophers; and Count Buffon, Dr Hutton, and many other modern naturalists,
see

see and acknowledge the marks of water in all parts of the superficies of the globe: but such is their bias to the system of fire, that they attempt to convert all the rocks and strata of the globe into so many lavas of different colours and structures; and in order to countenance and assist their favourite agent, with all the powers of a heated unguarded imagination, one goes up to the source of all fire, in order to have the solid parts of our globe melted down in the sun; another goes down to the subterraneous regions, and blows up his fire there to a sufficient degree of heat to melt all the superincumbent rocks and strata to the degree of fusion, even when immersed under the waters of the ocean, which is, I think, a new method of fusing earthy matter by fire.—Others again are content to honour this agent with the formation of some few of our strata, such as the basaltes, and a few others of nearly a similar appearance; but after all that they have advanced, or can advance to countenance this hypothesis, it is certain that none of the rocks and strata, which are a part of the solid superficies

ficies of our globe, exhibit any of the real marks and characters of being formed by fire.

The quality, component parts, interior structure, and appearance of our rocks and strata, are very distinguishable from slags or lava. Dr Hutton acknowledges this in the 66th page of his Theory of the Earth, where he says, that “ a fusible substance, or mineral composition in a fluid state, is emitted from those places of the earth, at which subterraneous fire and expansive force are manifested in those eruptive operations. In examining these emitted bodies, men of science find a character for such productions in generalizing the substance, and understand the natural constitution of those bodies. It is in this manner that such a person finding a piece of lava in any place of the earth, says with certainty, Here is a stone which had congealed from a melted state.” This passage is abundantly distinct, and I will say farther, that it is generally very easy for every unprejudiced naturalist to distinguish a real stone from a piece of slag or lava. The basalt is a

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real

real stone, which all modern philosophers have set down as belonging to the class of lavas ; but I have made it evident in my essays, that the basalt is a real stone, the component parts of which I have pointed out ; and I have made it appear, that there are in several places many and extensive strata of this stone, which are disposed in their stations among other strata of different characters and qualities, which are placed above and below the several strata of basalt, and these strata of basalt spread out as wide, and stretch as far every way as the other different strata among which they are ranged ; and therefore, no man, who understands the real structure of the superficies of our globe, will pretend to say that basalt is a lava, unless he says that all the other strata which accompany basalt are also lava. Where strata of basaltic rocks are blended promiscuously among strata of different rocks, it is necessary either to call them all strata of lava or strata of stone. Dr Hutton indeed talks in his Theory of inserting a lava, viz. basalt, among other strata of different qualities ; but I would ask the Doctor how he is to lift up

up the superincumbent strata to a sufficient and equal height from the strata below them, for many miles extent every way, and to keep them asunder, until such a quantity of melted lava is poured in as will fill up all the extensive empty space to form the new inserted stratum. I am speaking of regular and extended strata, which belongs to the natural history of basalt, and I can shew Dr Hutton a considerable number of strata of basalt, blended stratum super stratum, among other various strata of different characters and qualities, among which are a considerable number of strata of pit coal; and some of these coals are in immediate contact with strata of basalt, as the immediate roof and pavement of the coals; and I can shew him all these several strata, with their concomitant strata, in a stretch of many miles; and I can shew similar phenomena in West Lothian, in Ayrshire, and in Fife, &c.; and, therefore, it is difficult to believe that basalt is lava, unless we also believe that seams of coal, and all their concomitant strata,

strata, likewise are lava, which sounds very like an absurdity.

It appears to me rational, and even necessary to suppose, that if the strata were consolidated and cemented by the heat and fusion of subterraneous fire, all the strata, which have a tendency to, and may easily be hardened by fire, would be found in an indurated state; but this in fact is not the case,—so far from it, that it is well known to every person who takes the least notice of these things, that we find in all countries great numbers of tilly and argillaceous strata, so very soft, that they differ little from a mere sediment, from which the water has been pressed out, and which decomposes and falls to a mere sediment or clay, almost immediately upon being exposed to the external air: And it is remarkable, that these soft argillaceous strata are commonly situated immediately above and below very hard strata of indurated stone, upon which the external air has no sudden visible effect. How shall we account for this fact upon this hypothesis? It cannot be pretended, that these soft strata contain any marks or characters

racters of being consolidated by the heat and fusion of fire; for they are not consolidated nor cemented at all, but only compressed by the superincumbent weight of strata; nor can it be pretended, that they are not capable of being hardened by fire. In fact, we know the contrary by experience, as they are every day hardened in our open fires, and in proper kilns, for various purposes, and to various degrees of solidity and induration. If subterraneous fire had produced the solidity of our rocks, these soft substances would have been indurated, as well as their concomitant strata. But these soft strata are a proof, that our rocks are cemented by a terrene, sparry, and siliceous fluid, which is, by degrees, inspissated and hardened by the pressing out or evaporation of superfluous moisture; and they also prove, that these argillaceous strata can only be consolidated and cemented by fire, which has not been applied to them. We can only select a few facts which oppose this system. The instances to be found in the book of nature are endless.

III. The third proposition which we are to consider in our author's Theory of the Earth, viz. That the rocks and strata, which were formed and consolidated beneath the waters of the ocean by subterraneous fire, were afterwards inflated and forced up from under water, by the expansive force of the same subterraneous fire, to the height of our habitable earth, and of all the mountains upon the face of the globe, is an hypothesis as singular and extraordinary as the consolidation of strata beneath the waters of the ocean by the heat and fusion of fire. Most of the operations and effects of subterraneous fire, that we have any knowledge of, are outrageously violent and destructive, and only produce disorder and ruin. If the bed of the ocean was really to be forced up by subterraneous fire to the height of our mountains, we might expect to find as great confusion and disorder, and marks of the ruins of a world, among Dr Hutton's mountains as among Dr Burnet's; but I have shewed, in my Natural History of Mountains, that the strata of our real mountains are as regular as in any of the plains.

plains. In truth, I have not seen such regularity of the strata any where else as among the highland mountains of Locharber, which are the highest in Britain.—The local examples, which I have pointed out there, will evince the truth of this assertion to any who wish to ascertain the fact.

Our author lays great stress upon the phenomena of mineral veins, and of the ores and other substances found in them, to support and confirm his fiery system; but, in truth, every appearance of mineral veins, and of their contents, point to water with a distinct and legible index, as the chief agent in their formation, &c. which subject I have investigated and explained in my Natural History of the Mineral Kingdom.

Upon the supposition of our author's Theory of Mineral Veins being true, all our veins should be wide above, and narrower below, which is not found true in experience, very many of them being exceeding strait and narrow for many fathoms next the surface, which are very wide further down; and if this Theory
was

was true, every substance found in these veins should be the hardest in all the bowels of the earth, because the force and violence of the subterraneous fire would have a much freer passage through these open fissures, than through solid unbroken strata of several thousand miles of thickness; but this, in truth, is not the case, the inside of many of our mineral veins being exceeding soft and argillaceous.—Again, upon the supposition of the contents of our mineral veins being formed by metallic steams, forced up from below by the influence of subterraneous fire, our mineral ores should be all pure and unmixed with earthy or stony matter, which is not so; and moreover, upon this hypothesis, no metallic or mineral ore would be found out of the cavities of mineral veins; but neither is this the case; on the contrary, every mineralist knows very well, that gold, silver, copper, tin, lead, iron, &c. are commonly found, in a dispersed state, in large and smaller grains, flowers and masses, throughout the body of many of our rocks and strata, intimately mingled with their composition as one of the component

ponent parts of such rocks and strata.— Gold is generally found in grains of various sizes, mixed in the composition of many rocks and strata, and the origin of gold-dust is from the decomposition of the superficies of these rocks, which is washed down by the floods, and deposited in the beds of rivers. Iron is blended in great quantity in the composition of most of our rocks, and so abundantly in some of them, as to be worth smelting out for use; and, moreover, we have in many places great numbers of whole strata of iron stone so rich as to be equal, if not to exceed, the best of our iron ores in the produce of the furnace. In working downwards, many of our mineral veins are cut out, and fail at various depths, by a different stratum coming in below, which the vein does not penetrate. The rich vein of lead at Llangunog, in Montgomeryshire, which was five yards wide of solid ore, was cut off below in this manner:

A bed of schistus came in at a certain depth below, which cut out both the ore and the vein so entirely, that no vestige of either entered the schistus, or could ever

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after

after be found. Extensive trials were made on all hands to no purpose, as neither vein nor ore ever appeared. These circumstances do not agree with the idea of our ores being formed by mineral steams, forced up by subterraneous fires; and, therefore, we must acknowledge, that the substances of which our ores have been formed were poured into our veins by water from above, as well as the various spars and all the contents of mineral veins.— There is a curious and surprising mixture of many different substances in several mineral veins. In some of them, we find lead, copper, silver, and several other metallic and semi-metallic ores; and, in the same vein, we find calcareous and siliceous spar, with a variety of other stones and mineral matters of various colours, qualities, and degrees of hardness; and we frequently find many of these, and sometimes all of them, blended together in the concavity of the same vein. Every phenomenon of these different ores and different stones proves to ocular demonstration, that all the different substances in the composition were poured in from above, and mixed together

together while in a humid or fluid state, and that they were afterwards consolidated together into such compound masses as we find them.

IV. The fourth proposition offered to our consideration, in our author's Theory of the Earth, is also pretty singular, which is, that these operations of nature, viz. the decay and waste of the old land, the forming and consolidation of new land under the waters of the ocean, and the change of the strata now forming under water into future dry land, is a progressive work of nature, which always did, and always will go on, forming world after world in perpetual succession.

This hypothesis agrees pretty nearly with Count Buffon's, only that the Count brings about his successive changes by a watery process, without the agency of fire, after having the original matter of the whole globe once thoroughly vitrified in the sun. Both the Count and our author strenuously insist upon the waste of the superficies of the mountains, and of the rocky shores of the ocean, by the force of the tides and storms,

storms, as an infallible proof of the gradual destruction of the existing dry land, and they both infer from hence the successive changes of habitable worlds as a necessary consequence. I have in my *Essays* fully investigated and explained these matters. I have pointed out the utmost extent of the waste of the mountains ; and I have acknowledged, that the weight of mighty waves, propelled by the tides and stormy winds, have powerful effects in undermining and wasting the rocky shores ; but then I have made it evident, that this waste and destruction only advance to a certain length and degree, where it stops ; and I have drawn the line, and pointed out the depredations of the waves with some exactness ; and have made it evident to our senses, that hitherto they come, but no farther.

In some places, the sands are interposed to defend the rocks, and the very flow diminution of the sands by attrition is abundantly made up by fresh supplies furnished by the rivers. In other places, the rocks are covered by a shelly incrustation, the work of small testaceous tribes, which perfectly defends these rocks against any
injury

injury from the waves. We may suppose, that all or most of our maritime coasts were at first exposed to the ravages of the ocean. At present, the greatest part is defended by the sands and testaceous incrustations; and it is rational to suppose, that, in the course of time, all the shores of the ocean will be perfectly defended by these means. With respect to the real encroachments which the sea has hitherto made, or may hereafter make, upon the land, I think we may safely conclude, that a million of acres of new land have been made from the sediment of the rivers for every single acre of the rocky shores that has been wasted by the waves of the sea.

This is no supposition; it is a fact abundantly evident to our senses; and it is a sort of retrograde operation towards the successive change of worlds contended for by our philosophers.

Dr Hutton investigates a considerable number of fossil bodies, and explains their phenomena to countenance his own hypothesis. It would extend this Preface to too great length, were I to examine what he has advanced upon them all.

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At present, I will only take notice of the testaceous tribes of the ocean. He tells us, that these exuviæ, being found in the body and composition of our rocks and strata, is a clear proof, that those strata were formed by water, which is so far true. I also assert, that these exuviæ, and all the other remains of plants and animals found in the body and composition of our strata, is a decisive proof that the strata were formed by the agency of water; at the same time, I positively deny, that our strata were formed beneath the waters of the ocean. The natural history of the formation of our strata is fully explained in the second Volume of my Essays upon rational and mechanical principles, to which I refer for satisfaction on this topic. In my opinion, our author's philosophy is not more exceptionable in any part of his Theory than in treating of marine testaceous animals, as he makes these in effect to be very extensive creators of matter, which is exalting them much too high in our system of things. The Doctor says, that one fourth part of the solid bulk of our globe is composed of limestone, marble, and

and other calcareous matter, which I think is giving it too great a proportion. My general observations have been pretty extensive; and, as far as I can judge, all our limestones, marbles, chalk-stone, and clay-marl, which is soft limestone, and all other calcareous fossil substances, may amount to about a seventh or eighth part of the solid bulk of the superficies of the globe, which is a great deal indeed. Now our author asserts, in plain terms, and in several parts of his Theory, that this immense bulk of solid calcareous fossil matter was all of it produced from the remains of the testaceous tribes of the ocean. In my opinion, the proposition may be reversed; and we may with more truth assert, that the calcareous matter produced them, than that they produced it. Snail-shells are found in great numbers near old stone and lime walls; yet we never imagine, that these walls were produced by snails. It is almost evident to our senses, that these animals find the calcareous matter in a fluid state mixed in the waters of the ocean and the land, which they collect and use to make shells, coral, &c. To say that they

they produce this matter, is much the same as to say that they create it. Matter is only changed from one form of existence to another in the reproduction and growth of animal and vegetable bodies, but they really produce no part of matter that did not exist before in another form. I grant, that the exuviæ of testaceous animals are found in great abundance in many of our limestones and marbles, but not in all of them. There are very extensive rocks and strata of the mountain-limestones, and marbles of various colours, texture, and degrees of hardness, in which not the least particle of shell or coral is to be found.

These shells are also found in several other strata besides the calcareous, all which only proves, that these marine exuviæ were blended in the mass of chaotic matter when these several strata were formed; but to say that these animals can produce any particle of matter, is not good philosophy. We know, that calcareous matter certainly exists in a dissolved fluid state, mixed in abundance with the waters of the ocean, which is separated from the water in considerable quantity, in the common

mon process of making salt of sea brine. How the testaceous tribes make use of it in making shells and corals, is too nice a process for my investigation. Shells and corals could not exist, as we find them in the body of the rocks and strata, upon the supposition of these rocks being consolidated by the heat and fusion of fire, because a smaller degree of heat than is sufficient to bring our rocks to a state of fusion, would calcine all the shells and corals, with the limestones to boot; and when once they are calcined, they are no more shells, &c. but quick lime, to which they would fall with the least humidity; and the whole bowels of the earth, as far as we penetrate, is full of humidity.

In short, few of our author's conclusions are defensible, and no wonder, when he warps and strains every thing to support an unaccountable system, viz. the eternity of the world; which strange notion is the farthest of all from being defensible. All parts of nature, the minute as well as the grand and magnificent, proclaim aloud, and point out in legible characters the infinite power and skill of the

all-wise and benevolent Creator and Preserver of the universe. The Supreme Being hath highly favoured us with an exalted station, and hath given us the image of his own attributes. We daily enjoy the fruits of his care and benevolence, and we feel the effects of his goodness, whether we advert to and acknowledge it or not. The impressions of divinity are legibly stamped on all the works of God; and when we clearly behold the characters of ineffable wisdom in the great plan of creation,—of infinite skill and intelligence in the contrivance, disposition, and fine fabric of all the parts of nature,—of almighty power in producing all things and upholding them,—and of exuberant and unbounded goodness in communicating good to all animated nature, we then have exalted ideas of the Supreme Being; and if we reflect upon our own distinguished rank and situation in the scale of beings, and of our privileges and powers of acquiring knowledge and promoting mutual and social happiness, our hearts will exult in the display of the glory of the Creator in his works; and if we believe that the

Creator

Creator and Governor of the world protects and cares for us, our hearts will overflow with grateful love of the Deity ; we shall then rejoice in his works and in his goodness.

But sceptical notions have a pernicious influence in damping the sacred fire in our hearts, in cooling the ardour of our spirits, and in blotting out the native impressions of the Deity stamped on our hearts. The wild and unnatural notion of the eternity of the world leads first to scepticism, and at last to downright infidelity and atheism. If once we entertain a firm persuasion that the world is eternal, and can go on of itself in the reproduction and progressive vicissitude of things, we may then suppose that there is no use for the interposition of a governing power ; and because we do not see the Supreme Being with our bodily eyes, we depose the almighty Creator and Governor of the universe from his office, and instead of divine providence, we commit the care of all things to blind chance. Like a mob, who think they can do well enough without

out legal restraints, depose and slay their Magistrates. But this is rebellion against lawful authority, which must soon end in anarchy, confusion, and misery, and so does our intellectual rebellion. How degrading is infidelity! how miserable must a thinking man be in distress, who does not believe that there is at the head of the creation, a good, intelligent, and powerful being, who cares for his welfare through all the stages of existence!

That Dr Hutton aims at establishing the belief of the eternity of the world, is evident from the whole drift of his system, and from his own words, for he concludes his singular theory with these singular expressions: " Having, in the natural history
 ' of the earth, seen a succession of worlds,
 ' we may from this conclude, that there
 ' is a system in nature, in like manner
 ' as, from seeing the revolutions of the
 ' planets, it is concluded, that there is a
 ' system by which they are intended to
 ' continue those revolutions. But if the
 ' succession of worlds is established in the
 ' system of nature, it is in vain to look
 ' for any thing higher in the origin of the
 ' earth.

‘ earth. The result, therefore, of our present enquiry is, that we find no vestige of a beginning,—no prospect of an end.’

Thus, our modern philosophers labour hard to confirm their favourite scepticism, &c. by all possible means; or, in other words, they labour hard to rob us of our best inheritance, both here and hereafter, —to sap the foundations of our belief in revelation, and of the superintending care and love, and of the over-ruling providence of the all-benevolent, all-powerful God, our Saviour, who cares for us, and upholds us through all the stages of our existence,—and like actual robbers, these philosophers give us nothing in exchange for our natural inheritance. If they say that we are poor mistaken ignorants, and that they wish to convince us of our error,—this is worse than nothing. If we err in charity, let us live and die in this error. It is more happy to live in a full persuasion,—in a feeling sense of the love of God and man, while here, and in the confident hope of eternal felicity hereafter, than to suppose that there is no such thing,

thing,—that these divine faculties and propensities of our souls which make us capable of loving God and man,—of admiring God in his works, and of ranging thro' his creation with sublime delight,—shall perish for ever, and sink into the horrible gulph of *non-entity*.—Let us turn our eyes from the horrid abyfs, and stretch out our hands, and cry, Save, Lord, or we perish!

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PART I.

The Natural History of the Strata of Coal, and of the concomitant Strata.

A SEAM or bed of coal is a real stratum, which is found to be fully as regular as any of those other concomitant strata found in the coal field, lying above and below the coal, or indeed of any other of the various strata which compose the superficies of our globe.

There are in many coal countries, and in many coal fields, a considerable number of strata or beds of coal, of various qualities and thickness, placed *stratum super stratum*, with a great variety of other strata interposed between them; and sometimes *different* strata or seams of coal are so near to one another, that two, three, or more of them are cut through and worked in one pit. Every stratum of coal has some degree of declivity or slope, and a longitudinal bearing, and it

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stretches

stretches as far every way as the other strata which accompany it ; and therefore it must be concluded, that coal is not an adventitious recent production, but that every stratum of it bears its proportion in composing the superficies of the globe, and that the strata of coal are coeval with the other strata which accompany them.

As there is nothing so effectual as local examples to enable us to form proper ideas in enquiries of this nature, let us go to the rocky shores of the ocean, or to some river which has cut deep into the rock, and chuse out a fair and lofty section of the strata ; but care should be taken to chuse a proper section : Now a section that is cut in a line parallel to the bearing of the strata, is not a proper one, nor should the strata be too thick, as very thick strata of stone are apt to be broken transversely from the beds of the strata, and it is not easy to distinguish the real beds or stratification of the rock from the transverse cutters. I have frequently seen very thick beds of stone broken transversely into such equal and parallel divisions, that it required a good deal of attention to distinguish the real beds of the strata from these transverse cutters.

The best section for assisting our ideas, to form proper notions of the disposition of the strata, is one cut in a line nearly parallel to the declivity of the strata, that is in a line nearly from dip to rise,

rise, and where the strata are mostly thin, or of middling thickness, and the divisions of the several beds perfectly distinct. In such a section the several strata of various thickness and qualities are seen lying one above another, in as regular order as the leaves of a book, or a stack of planks.

If the strata decline a little with an easy slope, the section is the better adapted for this examination, as in that case the one edge of each stratum will dip down gradually out of our sight, and the other edge will be seen to rise up quite to the grass roots; and this order, in the disposition of the strata, is the most convenient imaginable for society, as it favours the discovery of working of coals, quarries, &c.

We find, that strata of coal do not always continue so good and regular so near the surface of the ground as some others of a harder texture. Limestone, whinstone, basaltes, and many other hard rocks, continue firm and good quite up to the superficies of the strata; whereas, on the contrary, many of the softer and weaker strata crack and crumble, or dissolve, near the surface, and the superficies of such strata decompose, and fall into sandy particles, which are mixed with the soil, or carried down the stream.

Many coals are not more goodly to look to near the surface than a heap of soot, and many
beds

beds of fine free-stone decompose, and exhibit nothing but a layer of sand immediately below the upper soil : Nevertheless, further down, under proper cover, the seams of coal, and other soft strata which accompany them, acquire strength and consistence, and preserve their thickness and their station one above another as regularly as other harder strata.

A fair and regular section of the strata, if it be a lofty one, is a magnificent and a pleasing sight. If we look up to the summit of a magnificent pile of strata, we perceive that they keep the same distance from one another above as they do below. Let us fix (for example) upon any two distinct layers, or strata, at several yards distance from one another, and stretch a horizontal line below, from the base of the one to the base of the other ; we will suppose that the line measures a hundred feet : Now, if the same length of line is stretched horizontally up at the surface, we will find that it spans them above as well as below, and that they are nearly the same distance from one another. The upper edge of every individual stratum in the section is called by Scotch colliers the *crop* of it ; and if it appears to the day, it is called the *out-burst* of the stratum. In England, they say it *bassets out*. Now, as the distance betwixt the two different strata is a hundred feet at the surface, and the same

same below, it will be found, that the strata of this section keep the same line of bearing, and the same declivity or slope for half a mile, or any given distance; and in that case the two layers or strata fixed on will continue at the same distance from one another all the way, so long and so far upon the line of bearing, as the strata preserve the same degree of declivity. If they turn flatter, or nearer to the horizontal position, then the crops of them will be found at a greater distance; but if they are elevated to a greater degree of slope, or nearer the vertical position, in that case, they will be found nearer to one another, in proportion to the greater or lesser degree of slope.

From this observation it appears, that the same class or range of strata always run parallel to one another. What I mean by a range or class of strata, is any number of strata that lie contiguous to, and accompany one another, and that are disposed one above another in the same place; as for instance the number of seams of coal and the other strata which accompany them in the same coal field. These are all disposed one above another in regular order, as I have shown in the section under review, and they all run parallel to one another to any distance; for if one of them suffer any interruption, disturbance or change, they generally all suffer the same, and when they
have

have got over such trouble or interruption, they all floor regularly again, so that the parallelism of the same range of strata is always preserved.

Every stratum in a whole range, or class, or coal field, is spread out to a vast extent in an inclining plane, we may suppose of a mile, or of several miles square, like an inclining field, or face of a country. A dead level line, drawn through this inclining plane, is called the bearing of the strata, and another line, drawn right across the dead level or bearing, is called the declivity of the strata, or the dip and rise of the strata. We generally can see but a very little way from the rise to the dip, or along the line of declivity of the strata, because the strata soon dip down out of our sight, and generally a great number of other strata come on above them; but, on the contrary, we can sometimes trace the same individual stratum or number of strata along the surface, or dead level line, for several miles; and therefore we may properly call this the longitudinal line of bearing.

It very frequently happens that the strata stretch or spread as far upon the latitudinal line of declivity as they do upon the longitudinal line of bearing; but then we cannot see them so far. We often see the superficies of the strata in different places upon the line of bearing bursting out, and appearing to the day, in rivers, rivulets, rocks,

rocks, scars, &c.; and we frequently work quarries, and especially coals, to a considerable length upon the stretch of this line; whereas the strata upon the stretch of the line of declivity are soon concealed out of our sight. From these observations it appears, that every individual stratum in the whole section keeps its station where you see it placed, and that it spreads as wide and stretches as far as any of those which are placed above and below it, which perhaps may be for several miles every way. Now a seam of coal being a regular stratum, it must follow of consequence, that when the crop or outburst of a seam is once discovered, it will spread as wide every way as any of the other strata which are found to accompany it.

The stratum which is placed immediately above the seam of coal, is properly called the *roof* of the coal, and the stratum which is placed immediately below a seam of coal, is properly called the *pavement* of the coal. Now these three, that is, the stratum of coal, and its roof and pavement, with the other concomitant strata lying above and below them, always preserve their stations and parallelism, that is, they are all stretched out and spread one above another upon the same inclining plane, and they have the same line of bearing and the same line of declivity.

When .

When a young naturalist has viewed a few regular sections of the strata, and has considered a little the stretch or spreading out of the regular strata, as described above; when he afterwards descends into a coal-work, and is shewn the sections of the seams of coal, and other strata cut through in sinking the pit; when he examines the seam of coal which they are then working, and finds it preserve an equal thickness between roof and pavement, perhaps for several hundred yards from the pit bottom; when he has seen the whole coal wall, that is the unwrought coal; and all the boards or rooms in which the colliers are working, with a prodigious number of coal pillars left for supporting the roof, and finds the coal every where of nearly the same thickness, and preserving nearly the same declivity or slope, the first thing that strikes his imagination, next to the novelty of the whole scene, is the extreme regularity of the stratum of coal so deep down, and to such an extent below ground; and he will perhaps imagine it a very easy matter to pursue and work out a seam of coal to any extent, even through the whole length of the island; but experience does not find it so easy a task as a sanguine theorist may be apt at first to imagine.— Experience meets with numberless rubs and interruptions in working coal, many of which occasion great trouble and expence, and some of them

them prove the loss of the coal altogether, either by its being cut off, or rendered unfit for working with profit.

An accurate knowledge of the strata in a coal field is indispensably necessary to a coal-master ; and to obtain this knowledge, he should himself enter the pits, mines, and levels sunk and drove in the coal field. In these he will see a great number of the different strata of stone, and of the other coal metals, thick and thin, hard and soft. An accurate coal-master will make himself well acquainted with the quality, colour, and thickness of each of these, and how far each of them is above or below such and such a seam of coal. He will carefully consider the order of the different strata, as they lie *stratum super stratum* with respect to one another, by which means, when he sees any one of them, he knows what others are to be found next to it, both above and below. Now this knowledge is often of singular use to him ; as for instance, when the coal is thrown either up or down by one of those slips, which I am by and by to describe. In that case, the coal appears to be lost. Well, what is he to do in this difficulty ? The coal is of too much consequence to be given up. What method then is to be adopted in order to recover it ? That he cannot properly resolve upon, until he knows first how far it is thrown

out of its regular course, up or down. But how is he to know how far the coal is thrown off its former level? The readiest way to be master of this interesting point, is to pierce the stone, or rather strata, which faces the workmen, where the coal is cut off and lost; and if he knows it with certainty, he is encouraged, as in that case he knows pretty nearly how far the coal is thrown off its ordinary level, either up or down; and he can then judge which is the most proper method to recover it with least expence of time and money. The coal is sometimes thrown a great way out of its former course by great dykes and slips, which frequently make it necessary to search for it upon the other side of such *troubles*; and many accidents happen which make it sometimes necessary to shift the former station altogether, and to sink new pits, &c.; in which cases, an acquaintance with the history of the strata which accompany the coal becomes absolutely necessary, and the want of it makes many to grope in the dark, and often to commit blunders at a great deal of unnecessary expence and loss of time, and sometimes to miscarry altogether, when they might have succeeded better had they but known what they were about, and been master of the history of the strata which accompany their coals.

Some of the strata which lie near the coal are frequently seen cropping out in rivulets and other places

places, where the superficies of the strata appear, and an expert coal-master knows what use to make of such discoveries. He will be very careful to investigate all he sees from time to time, until the place, and disposition, and other phenomena of all the strata in the coal field are become familiar to him.

I shall now give a history and description of such breaks and interruptions of the regularity of the strata as are commonly met with in working coals.

The slips, dykes, gashes, and other accidents which are met with in working coals, are all of them in general, and not improperly, called *troubles* by Scots colliers.

I. The *slip*, properly so called by the English colliers, but improperly called a *dyke* by most of the Scots colliers, is the most frequent accident or interruption which we meet with in working coals. In a slip the strata are all cut or broke asunder, frequently in a straight line, though sometimes in a curved line, and those upon the one side of the breach or section are flipt down a considerable number of feet, perhaps many fathoms below the edges of the same strata upon the other side of it. In some coal fields, the metals or strata are thrown up by one slip as much as they were thrown down by another, and in other fields all the slips which we meet in working

ing away the coal towards one point of the compass are up slips, which in course would be all down if you were working towards the opposite point.

There is no coal-work of any considerable extent without slips. In pointing out a slip to a young student in this branch of natural history, it will be proper for his conductor to shew him the coal wall in perfection, as near the slip as he can, where he will find the coal nearly of the same thickness as in other parts of the work; and by shifting the candle slowly forward along the coal wall a few yards, he will see the slip. If it be a down slip, he will see the coal beginning to be cut off first above near the roof, and so downwards, by degrees, to the pavement, not always in a perpendicular, but generally in a sloping line, though some slips stand much nearer the perpendicular than others. When, in a down slip, the coal is cut off in this manner, you will meet with stone or other metals * instead of it, first near the roof; and the stone continues to meet the workmen in the face, or in the place where the coal should be with a slope downwards, until at last, down at the pavement, the whole
stratum

* When I use the word *metals*, in treating of coal, I mean such strata of different colours and qualities as are commonly found accompanying seams of coal.

stratum of coal is cut off, and no more of it remains in sight. To a person of no experience in these matters, the coal in this instance appears to be cut off altogether, nor would he know what was to be done in order to find it again; but an experienced coal-master has pretty good rules by which he can recover it. As the coal in this down slip began first to be cut off at the roof, and so gradually downwards, until it was entirely cut off at the pavement; your conductor, with the point of a pick, can open up a little of the vise or fissure in the pavement, and in that fissure you will perceive some vestigia of the coal remaining. Sometimes an inch or two, or more, of the coal is seen going down in the fissure, but frequently nothing is found in the section or fissure, but a blackish soft sticking of clay, perhaps not above half an inch thick. I have seen the joint so very close, that there was hardly room to thrust the blade of a knife betwixt the two hard sides of the fissure, nevertheless the section or fissure continued to be distinctly seen with two smooth sides. It will then be proper to shew our young learner where the slip has been pierced by a mine; and when he has gone through the mine to the other side, he will see that from thence the same trouble becomes an up slip. Above, upon the other side, the coal began first to be cut off at the roof, but, on the contrary, it begins

begins here to be first lost below at the pavement, and the stone comes in instead of it gradually upwards, until all the coal is entirely cut off at the roof. You will find the coal flooring as regularly down, upon the low side of the slip, as it was above on the other side of it, before it was cut off; and if the mine has been made in the vise or fissure of the slip, you will see some dark vestige of the coal all the way through, from the place where the coal was cut off, upon the one side of the slip, until it floors regularly again, at full thickness, upon the other side of it. At least, you will perceive a section or fissure cutting all the strata in a slanting direction from where the coal is lost above, until it is found again below.

When we first meet with one of these troubles, we do not immediately know what to make of it, or how far it has thrown the coal up or down, unless we have pierced it before in some other part of the field, as they differ widely in magnitude, or in the number of feet, or of fathoms, they throw the coal off its ordinary floor or level; and they also differ widely in the confusion they make in the metals, and in the line of bearing; but they all agree in this one circumstance, that there is always a cut or fissure in the strata, though not always in a straight line; and that the section of the strata upon one side of the fissure

sure is always thrown or sunk down below the section or edges of the same strata, on the other side of the fissure.

Slips in the coals and coal metals are either parallel, direct, or oblique :

1st, By *parallel slips*, I mean such as cut the strata in a line parallel to the dead level line or bearing of the strata ; and the bearing in Great Britain, and other places in the same parallels of latitude, is nearly from north-east to south-west, excepting small spots or places where they have been partially warped or twisted out of the true line of direction by accidental causes, such as a different dip or declivity of the strata, which is occasioned by the waving and wheeling of the strata, &c. to be explained hereafter.

The effect of the parallel slip is this : When you are working a coal towards the dip, or pushing a mine towards the dip, in order to gain a greater breast of coal, you strike one of these slips, which meets you in the face as you push downwards, cuts off the coal, and throws it many feet or many fathoms up. Some of these slips throw the coal quite up to the surface, though you have sixty, eighty, or more fathoms of cover where it is cut off. The coal has generally the same, or nearly the same declivity or dip upon both sides of one of these parallel slips, and likewise the same bearing ; and, therefore, when the coal

coal is only thrown up a few feet, or a few fathoms, the interruption is easily overcome, by running a mine or level right across the strata, from the one side of the slip, until you cut the coal upon the other side of it. But when it happens to be a great slip, you have either a long mine to drive, in order to level the water upon the other side of the slip, and bring it to the adit or engine, or else you must remove the engine to a proper station, to gain as great a field of coal upon the other side of the slip, as it is able to drain. It will be easily conceived, that in this instance, what is an up slip from one side, is a down slip from the other; that is, when you are working with your face to the dip, and meet an up slip, if you were working upon the other side of it, and working with your face to the rise of the coal, it would be a down slip.

These parallel slips are frequently the occasion of our having such fine and regular sections of the strata as we often meet with upon the banks of rivers, cliffs of rocks, and the shores of the ocean. One of these slips, or perpendicular fissures, cutting the strata in a line, and that part of the range of strata which was without the fissure, or towards the crop of it, being undermined by water, or otherwise broken off, a regular section of the strata, from the top to the bottom of the rock, on the side which stood firm, is exhibited to view.

2d, The *oblique slips* are such as cut the strata in a diagonal direction across the slope. These slips differ but little from the former in description, only they throw the coal up or down in the same oblique direction, and they throw it to one side, out of the line of bearing, in proportion to the obliquity of the line of the fissure or slip to the line of bearing of the strata, and the number of feet or fathoms the coal is thrown up or down off its former level.

3d, The third species of slips, which I call *direct*, are such as cut the strata right across, nearly in a line from crop to dip. When you are carrying forward a breast of coal, which dips towards the north, and are working along the dead level line or bearing of the coal, with your face towards the west, and meet one of these direct or rectangular slips, if it be a down slip, the coal is thrown so far to the left hand out of the former line of bearing; but, on the contrary, if it be an up slip, the coal is thrown to the right hand, in proportion to the number of fathoms it is thrown off its former level, and to the quick or slow rise and declivity of the strata. In this case, when it is a down slip, a mine or level drift must be turned off to the left hand; but if an up slip, it must be turned off to the right from the lowest or level room, and carried in the vise or fissure of the slip, in order to level the coal, and winn it properly

upon the other side of the trouble. It may be proper to observe here, that you cannot depend with absolute certainty upon such mine or level for discovering the coal upon the other side of this trouble, until you first know that the slip is a single slip, for many large slips have several branches. In a single slip, which only throws the coal once up or down, you are sure to find the coal with a mine, as pointed out above, by keeping a good hold of the firm metals in the farther side of the mine, where the coal is to be found, that is, by cutting the edges of the solid strata in the farther side of the vise, or softness contained in the fissure of the slip. But if the slip consists of several branches, or, in other words, if there are two or three, or more slips near one another, which often happens before the coal is got clear of that trouble, and floors again as before, it requires farther attention. We sometimes meet with a range of troubles or slips, parallel to, and so near one another, that we must try to get beyond them all before the coal shall floor regularly. In that case, the mine or drift mentioned before is not sufficient. This mine is supposed to be driven in the vise of the slip, and the whole breadth or wideness of the mine is not above three feet; whereas the whole trouble, including the bundle of parallel slips, may be twenty, forty, or even a hundred feet broad, or
more;

more ; and, therefore, a cross mine through all the branches must be cut before the coal can be found and levelled by such a mine. When a parallel slip, an oblique slip, and one that cuts aright across the strata, meet at certain angles or points, they often produce a triangular piece of coal, of less or greater dimensions, in proportion to the distance these different slips happen to be from one another. Sometimes the sides of these gussets of coal are nearly of equal, and sometimes of very unequal lengths. When a great number of these different sorts of slips happen to cut and intersect a field of coal in all directions, they often make sad havock in it. A proper plan of the fissures and disturbances in such a field would much resemble a large sheet of ice, broken and fallen in, where pieces and fragments are to be seen of all shapes and dimensions, the edges of the fragments being elevated and depressed, or split by one another in all directions and in all degrees.

These slips, as well as all other troubles and interruptions met with in working coals, are generally looked upon only as real evils incident to the practice of colliery ; and it must be confessed that they are so, and that they often prove exceeding troublesome and expensive ; and moreover, they certainly are the most frequent interruption of the regularity of the strata ; but it is perhaps

perhaps the only coal trouble by which we reap any benefit. Contrary to what is generally imagined, a very obvious advantage to coal-mining arises from these slips. They are often a general good when they prove a partial evil.—By throwing the strata of coal up and down this way and that, they are spread wider over the face of a country; and the slips throw more of them up, so near the surface of the ground as to be within our reach, than we could otherwise possibly get at, were the strata to keep the same uniform stretch, bearing, and declivity invariably, without any interruption or breach of regularity.—A parallel slip especially gives us the same field of coal over and over again, as often as it is thrown down by a slip of that sort.—One parallel slip, if it throws the coal sixty or eighty fathoms down, or as much as you can reach with your level, or engine, gives you the same field of coal twice over in any given length upon the longitudinal line of bearing. Three parallel slips, in like manner, give the same field exactly three times over, and so on to any number, provided that there is a sufficient distance betwixt each slip, from crop to dip, to give an ample breast of coal; and the other sorts of slips have in some degree the same effect of keeping the coals floating near the surface, within our reach, which makes the slips a public good, when in fact they often prove a private evil.

When

When a great slip has many branches, or when there are many slips running parrallel, and near to one another, they often prove very troublesome and expensive. I have seen some of these very wide, and the metals betwixt each of the branches, being generally imperfect and tender, and dipping confusedly every way, make it difficult to get over them.

Sometimes the coal seems to floor regularly between the divisions of these great slips, but the compartments are so small, that although the coal should be found at full thickness, yet it is cut off again when we have advanced a few feet, or at most a few yards forwards in it. The coal is sometimes found pretty good between the grains of these troubles, and pretty regular, with the proper dip and rise; but it is much oftner found imperfect, soft, and uselefs.

When the coal is thrown forty or fifty fathoms off its former level, by a slip composed of several parallel divisions, which cut across the strata, it often alters the declivity, so that the coal shall lie much flatter upon the one side than the other of this trouble; in which case it is very difficult to calculate exactly how much the coal is thrown off the former level, and how far it is thrown to the right or left out of the former line of bearing. Where the superficies of the strata are seen in rivulets, glens, and other places, where the
the

the surface of the earth is broken, some imperfect notices may be obtained, if we are master of the history of the strata of the field; but if the surface is unbroken, and the strata covered with clay or sand, &c. the most skilful are in the dark until they have made trials by boring, or otherwise.

The facility with which boring is now performed by men of skill in that branch of business, with a good apparatus, is of great consequence to set us right in such difficulties, and in doubtful cases, at a moderate expence. Before boring was brought to such perfection, and became common, many expensive blunders were committed; and so there are still when that wise precaution is neglected. It is no uncommon incident in the history of collieries to hear of sinking expensive pits, and sometimes of erecting steam engines, where they had no coal to work when they got down, because they unfortunately happened to place their pits between two slips which were pretty close to one another, and ran parallel to one another. The metals, or different strata which they cut through in sinking such pits, perhaps might appear to lie fair, and to dip and rise regularly; but when they come to drive mines in the coal, in order to open it up for working in form, they find, when it is too late, that they have no coal of any consequence to
work

work upon. They are soon cut off by troubles on each hand, and all their expence and time is lost, which might have been prevented had they duly examined their field by boring.

I have already hinted, that some of the great slips have many parallel branches, between which branches, or parallel slips, the metals are imperfect, and in the greatest confusion and disorder; there are other great slips that throw the coal forty, sixty, or eighty fathoms up or down at once, that is, at one slip without any parallel branches in that place. When these are known, they are generally more easily conquered than such as are composed of many branches, because the metals are generally good and regular immediately upon the other side of the single slips; whereas the confusion and trouble continues, and is often very wide and difficult to get over, where many slips run near to one another. The single slips, or steps, for they are known by both names, are of various degrees of magnitude, from sixty or eighty fathoms, or more, down to a few feet, and even a few inches. When these slips are small ones, they are called *hitches* by Scots colliers; and it frequently happens that such a small hitch only cuts off a part of the coal, and that the other part of the thickness of the seam continues still in sight. In this case, the worst consequence generally is, that the coal is shaken,
tender

tender and foul, and continues so until you are quite clear of such trouble. If one of these small slips or hitches should not throw the coal above three or four inches off its ordinary level, yet, nevertheless, it will very sensibly affect the coal seam, and all the metals about it, as this trifling slip cuts through them all; and they are always in a less or greater degree soft, tender, and brittle upon both sides of the fissure; for which cause the colliers are generally obliged to contract their boards, or rooms, much narrower when they pass through one of these hitches, in order to save the roof until they are quite clear of it. These smaller slips are very frequent near the superficies of the strata, and much more so in some fields than in others. But the small hitches found at the surface seldom go far down; whereas the larger slips continue from the surface down, as deep as we sink, and cut through every individual stratum in their course.

There is yet one material remark to be made concerning slips, namely, that every one of them are not always equal in every part of the work; that is, all slips do not always throw the coal and concomitant strata an equal number of feet, or fathoms, off its former level in all parts of the same work. Some of them are very considerable slips near the superficies, or crop of the strata, and throw the coal, &c. a great many fathoms
off

off its former regular floor, or bed, which prove but small ones further down, towards the dip; and, on the contrary, some are great slips to the dip, and small ones near the crop. I have seen many of these that threw the coal several fathoms up or down near the crop, which grew less and less as we wrought down towards the dip, until they at last dwindled away to nothing, and were no more seen: And I have seen very considerable slips pretty far down towards the dip, which grew less and less as we advanced upwards, and at last dwindled away, and were no more seen, before they reached the crop.

I believe it may be observed, in general, that the slips which vary so much between the crop and dip of the coal, are commonly such as cut across the strata, either in a right or a diagonal direction. The parallel slips, I am persuaded, are generally more regular, that is, they continue to a greater length, along the bearing of the strata, to be a slip of so many fathoms as we found them at any given point.

It is exceedingly difficult to explain all the phenomena of every particular slip which we meet with in working coal, because they all differ from one another in some manner or degree.

All the slips found in the coal metals are mineral veins, and of that species of veins which are called by naturalists *perpendicular fissures*, and by

miners, *rake veins*; and as these veins are softer or harder, wider or closer between the sides, so are the slips *. Some of the slips are very wide betwixt the two sides of the fissure, and the cavity often contains heterogeneous or adventitious matter, frequently such as inclines to be soft and argillaceous; and the sides of such wide slips are generally soft, loose, and dangerous, as they cannot be mined either along or across the slip without securing the mine with timber. Other slips are hard and close, at least in some places upon the longitudinal line of them; and though the strata may be thrown a great many fathoms off the ordinary level by them, yet the two sides of the vein, or fissure of the slip, will be found in some places perfectly close together, though the fissure or joint will always be discernible to a skilful eye.

Again, some of the slips contain several species of heterogeneous matter, between the sides of the fissure, of a harder nature; such as pyrites, several kinds of spar and crystallizations, and sometimes lead ore, &c. I have frequently seen pyrites and large ribs of spar in several slips, and more than once a little lead ore in the collieries of Scotland; but Coalcleugh, in the north of England, is the most

* I have explained this subject more fully in Part II. where I treat of the natural history of Mineral Veins, to which I refer the reader.

most remarkable place for producing a great quantity of lead in the coal metals, of any I have yet heard of. There the lead cut off the coal, or threw it off its regular bed, as other slips do which contain no lead. The coal was found upon the other side of the slip, and wrought as usual, according to my information, and the lead was wrought with eminent success.

There are a great variety of lesser *troubles*, or disturbances of the regularity of the strata, such as *hitches*, *skews*, *backs*, &c. which are more local, and in general only affect one particular spot. These are not easily described, as no two of them are alike, and they are seldom of much continuance.

A *hitch* is a small slip, which only throws part of the thickness of the coal off its former level, and the other part of it always remains in sight, so that the coal is never quite lost with a hitch.

Skews and *backs* are only local joints of an irregular curved figure, which often resemble hitches when we first meet with them, but they only strike out a little way, and turn in again; that is, some of them describe a segment of a circle of lesser or greater dimensions, and others of them only prove a discontinued joint, which only affects a small part of the coal, and the coal roof, &c, but seldom extends to any great distance.

It

It may be proper to repeat here, for the sake of memory, that there are two circumstances peculiar to all slips and hitches. First, there is in every one of them a real section, or fissure, right across the beds of the strata; and secondly, the beds of this section, or cut, is split down so that the seams of coal, and other particular strata, floor lower down upon the one side of the fissure, or section. If the strata lie in a horizontal position, the fissure of the slip will be nearly perpendicular; but if the strata hang with any considerable degree of declivity, the fissure of the slip will be found in a slanting direction; as all these sections generally cut transversely, or right across the bed of the strata, or nearly so. I observed before, that every slip of the coal metals has a vise, or vestigia, which points out to a skilful eye which way the metals are thrown out of their former course, or level; and this vise is generally some imperfect remains of the coal; a soft sooty-like substance, or else some species of clay contained in the joint betwixt the two sides of the fissure of the slip. In an up slip, the coal begins first to be cut off at the pavement, and so upwards, by degrees, until all the coal is lost, in which case the vise leads up into the roof; and on the contrary, when it is a down slip, the coal is first lost at the roof, and so downwards, by degrees, or in a slanting direction, until the coal is quite

quite lost at the pavement; in which case the vise strikes down into the pavement; and this makes the vise of singular use to satisfy us which way the coal is thrown off its former level; and it is a guide to lead us the right way to find it again. Sometimes the roof presses down upon the coal, and cuts off much of its thickness, without any slip or hitch. This, in some places, will be of several fathoms extent, and in others no broader than the bottom of a pot. In some places, without any apparent cause, the coal turns foul, and mixed with stone or clay, so as to be good for little or nothing, for a less or greater extent.

II. The second great interruption of the regularity of the strata, and trouble met with in working coal, is a *dyke*. Dykes are very commonly found in many coal-works, and they are of various kinds, such as, 1st, Dykes of basalt, or other hard stone, which are commonly called *whin dykes*: 2^d, Dykes of imperfect stone: 3^d, Dykes of clay; in some of which the clay is chiefly of a homogeneous quality, and in others it is compounded or mixt with gingle, gravel, &c.: 4th, Dykes of gingle and of gravel, without any mixture of clay: And 5th, Dykes of sand.

I suppose that this species of coal-trouble was first called *dyke* from the resemblance of some of the

the lesser hard ones to a stone wall, or stone dyke, some of them being no thicker than a common garden wall; however, these dykes vary greatly in thickness as well as in quality, and the matter of which they are composed. They vary in thickness from two or three inches up, to a great many fathoms; in some instances, too many fathoms to be cross cut, or pierced through with a mine; in which case, they are obliged to abandon the present pits, and to search for the coal upon the other side. But these prodigious unconquerable dykes are not frequently met with.

A dyke, in the natural history of the superficies of the globe, may be called a crack, fissure, or chasm in the strata; the concavity of which chasm is filled up commonly with foreign heterogeneous matter, which appears to have been carried there by water, and poured in when the substance of which the dyke is composed was in a fluid state.

Some dykes of *whin*, and of other stones, are so hard that every inch of them in driving a mine must be blasted with powder. Besides these dykes of compact and indurated rock, there are others which are composed of softer and more imperfect stone, sometimes resembling fragments of the neighbouring strata packed into the cavity betwixt the sides of the chasm, and others are composed of an indigested mass of imperfect stony

stony matter. There are some of the hard stone dykes found pretty dry, even at a considerable depth below ground, and others are full of open cracks and cutters, and some of them have a longitudinal fissure in the middle of the dyke; these often let down a considerable quantity of water. The dykes composed of fragments of imperfect strata, resembling some of the coal metals, are seldom very dry.

The *clay dykes*, both the homogeneous and the compounded, are generally very dry; but on the contrary, the gingle, gravel, and sandy dykes always, at considerable depths, produce a great quantity of water, and especially below level, in flat and plain situations. At the same time, it may be of use to remark, that if one of these gingle or gravel dykes, or any others composed of open loose materials, happen to cross a glen, or dingle, or to point towards any low river, it may happen to drain the coal, and render the field dry, and *comeatable* as low down as that river or valley.

Dykes do not throw the coal seams and other strata off their former levels like the slips; but on the contrary, when a dyke is pierced through with a mine, the coal is commonly found upon the same level as where it was lost upon the other side. There are indeed some dykes which throw the coal, &c. a little off the former level, and these

these I will, for distinction's sake, call *slip dykes*. These slip dykes differ nothing in appearance, or in any point of description from the others which leave the coal upon the same level, but that they throw it less or more off the same level.

Dykes appear variously when you strike them first. Sometimes the coal continues good and clean, until it is entirely cut off by a wall of stone, that meets the collier full in the face. At other times, that is, in other dykes, they meet with foul coal several feet, and in some places even several fathoms before they touch the dyke. The foul coal upon the face of a dyke is plentifully mixed with sand, and other particles of stony matter, which renders it unfit for use. This is commonly called in some places burnt coal, the quantity of which upon the face of the dyke varies greatly in different places. Upon some dykes there will not be above two or three feet of bad coal, and upon others there will be two or three fathoms, or more. I have seen above four fathoms upon both sides between the clean coal and the stone dyke. There is no vise or joint in the dyke to lead them through it to the coal upon the other side, as in the slip; on the contrary, a solid body of stone meets them in the face, which exhibits no manner of vestige or leader whatever to point out which way the coal is gone, and therefore they are obliged to drive a
mine

mine through a dyke at all adventures, without being able so much as to guess at the thickness of it, until they find the coal upon the other side. However, when they have once pierced a dyke by driving a mine through it, they have then a near guess what it will be when they meet with it in another part of the field.

Some of the stone dykes are so hard, as I hinted before, that a mine in them can only be made with the help of gun-powder, and others, on the contrary, are so soft, and the stone they cut through so tender and rotten, that every foot of the mine must be lined or supported with timber. Thin dykes, which do not spoil the coal much, are commonly easy to be got over, but it is generally a work of much time and expence to pierce through some of the greater dykes; and, as I observed before, some few of them are so very thick that they prove an insurmountable barrier, so as to oblige them to search for the coal upon the other side.

The clay dykes are generally pretty easily pierced, but the mines driven in the clay are not always so easily secured. It is often exceedingly difficult to drive a mine through some of the gingle, gravel, and sand dykes, and especially at considerable depth below level, as they then contain a great deal of water, which disturbs and retards the progress of the miners.

III. A *gall* or *gasb* is very frequently met with in coal-works. A *gasb* is a crack or chasm in the coal, and in the concomitant strata above and below the coal. These galls or gasbes vary greatly from one another in magnitude, and in their mischievous effects. Some of them prove only to be a small chasm or crack, which does little more harm than to entender and spoil a small quantity of the coal upon both sides of the *gasb*. These are soon got over, the coal being always found upon the same, or nearly upon the same level on both sides of the trouble; but, on the contrary, many of the wider gasbes prove very troublesome and expensive. The chasms or fissures between the sides of the larger gasbes are generally filled with sand, gravel, clay, and other loose matter, which will run down upon the workmen, and choke up the mine they are pushing through, if they neglect to secure every inch of it with timber as they advance; for if it once begins to run, it may prove difficult to stop it, and it may bring such a press or weight upon the mine, that they may not be able to secure it afterwards; and, therefore, the best way is to take it in time, and to secure it with timber, step by step, as they advance, and to set their timber strong and close, in proportion as they see that circumstances require it.

In

In some coal fields they meet with gashes so wide (filled with sand, clay, and other loose matter) that the colliers call them sand dykes.— These are often very wet and difficult to cross, and sometimes altogether impracticable.

These gashes, and the dykes described above, are so like to one another in many instances of approach, that some of them are hardly distinguishable, are to be investigated upon the same theory in many respects, and seem to me to have originated from the same natural cause, *viz.* a crack or section, in a line across the strata, such as we see in miniature in brick-makers clay, spread out, and left too long in the sun; and these chasms being afterwards filled up with heterogeneous matter poured in from the surface; and this foreign matter so poured in is the real dyke, which separates the edges of the coal, and other strata, from top to bottom, where they are broken asunder by such chasm or fissure; so that the only material difference which I can find between a dyke and a gash is, that the foreign matter which fills up the chasm of the dyke is in some indurated, in others only dried to different degrees, whereas it always continues loose and generally very wet in the gashes.

In some coal fields several dykes run parallel to one another. Sometimes they are found to be two or three hundred fathoms asunder, and
often

often much fewer, the field of coal being divided by them into so many compartments, and each of the compartments between the several dykes and gashes, are subject to be disturbed and subdivided by slips, shakes, &c.

IV. Another formidable, and often a very dangerous interruption to their progress under ground in working coals, is a *shake* in the metals or strata which affects the seams of coal, and all the other strata above and below the coal. The shakes also vary considerably from one another, both in kind and degree. In some shakes, the coal and the other strata are only shaken, cracked, and broken to pieces, spoiled and made soft, tender, and useless, but remain at or pretty near their former thickness and position. These are commonly pretty easily got the better of, being seldom of great extent. The worst and most dangerous shakes are of two sorts, which, for distinction sake, I will call the *waving* and the *twisted*.

In the *waving shake*, the strata are not entirely broken and separated by a fissure or chasm, as in the slips and gashes, &c. but only shaken, cracked, and thrown into great confusion. When the coal enters into one of the waving shakes, it is seldom or never altogether lost, but it is always rendered useless,—commonly very soft, tender,
and

and shattery,—sometimes thicker, sometimes thinner,—generally waving up and down, yet preserving nearly the same stretch, bearing, and declivity. Some of these shakes do not continue long before the coal comes in, and floors again in its usual regularity and perfection; in other places they prove very wide and extensive, even up to several hundred yards, so as to make it necessary to look for the coal quite beyond them, and to open up the works of new.

Some shakes only crush and spoil the coal, make it tender and bad, but do not alter the thickness, nor the bearing and declivity of it; and it generally happens that this sort of shake only continues a few fathoms; in which case, the common method is to drive two or more narrow mines through it, until they come into good and firm coal upon the other side, and then to winn or open out the works of new.

The *twisted shake* is often more dangerous in its consequences than the *waving*, being sometimes (I do not say always) occasioned by a total interruption of the course or bearing of the coal metals, where the coal and all the other strata of the coal-field are entirely cut off by another range of strata, which are altogether foreign to the coal. This happens at the extremity of the coal country, both in the longitudinal line of bearing, and upon both sides where other strata commence entirely

entirely of a different quality from the coal metals. But this is not always the case. There are frequently twisted shakes to be seen in the middle of the coal-field. It is very difficult to describe a twisted shake, as it exhibits the utmost confusion imaginable in all the extremes, from the regularity of the strata. The strata or metals, in some parts of a twisted shake, appear waved and distorted several ways,—bent round to various segments of a circle,—dipping this way and that in confusion and disorder; fragments of the coal and other strata appear in nests here and there, without continuity, or any other vestige by which to trace out the coal; so that when a large shake of this sort is met with in the middle of a coal-field, the best expedient is to look for the coal upon the other side of it, where the metals are found to floor, and stretch again fair and regular.

But all the twisted shakes are not so formidable. They are found in all degrees like other coal troubles; some of the smaller sort can be got the better of without much expence of time or money, and without quitting the present pits, and some of them only continue a few feet.

I shall here point out a few of the many places in the Lothians, where the lovers of mineral knowledge may behold the superficies of the strata
laid

laid bare for their inspection; where they may see strata of coal, and its concomitant strata, both above and below, and likewise strata of ball-iron stone, which is now become an article of much value and consequence in Scotland.

The vertical or edge seams of Gilmerton and Loanhead are the nearest coals to Edinburgh, of any that have been yet discovered and wrought.

The superficies of several of these seams of coal, and of their concomitant strata, are to be seen when the tide is out, within flood mark, between Edinburgh and Musselburgh, near Duddingston fire-engine; and there is a pretty good section of them to be seen in the high road (upon the left hand) from Edinburgh to Dalkeith, betwixt the parks of Drum and Edmondstone *. But the best sections of these coals, and of the strata which accompany them, are to be found and seen in the levels and cross-cut mines in the coal-works of Gilmerton.

The rivers North and South Esk, in Mid-Lothian, cut through a remarkably rich coal-field. These two rivers join in one before they reach Musselburgh, where the united Esk falls into the tide. Though the two Esks are but small rivers,
yet

* Since writing the above, these sections are concealed by a stone wall, and the ground is levelled and planted.

yet they have in many places scooped out or worn very deep channels; and there are many fine sections of the strata of coal metals to be seen upon their banks in the deep ravines.

There are good and regular horizontal strata of the coal metals, and of post freestone, to be seen in the bed, and upon the banks of the river Esk in several places, below the junction of the two branches of it, particularly near the corn-mills of Cowpits colliery, where some pretty good sections are to be seen in quarries upon both sides of the river, dipping towards the north and north-west, with an easy slope.

There are several sections of the flat or horizontal coal metals, a little way above the ford of the North Esk upon the Newbattle road from Edinburgh, and likewise below the ford near the iron mills.

The bed or channel of this river is remarkably deep about Roslin and Hawthornden, where abundance of high and romantic rocks appear upon both sides; but these rocks will not afford much instruction in this science, because they are chiefly composed of thick strata of post freestone, running parallel to the bed and course of the river, which causes a dull uniformity in the appearance of these rocks; I mean with respect to stratification; but as the rocky banks of a
small

small river, they are abundantly magnificent and curious.

Between Roslin and Auchindinny bridge, there are several fine and lofty sections of the strata of coal metals upon both sides of the river, among which there are several thick beds of red and white post stone, with a variety of such other strata as commonly attend coal; and there are a considerable number of coal seams both above and below these sections, many of which have been, and continue to be wrought. The sections of the strata in this part of the river lie flat or horizontal, and in some places these flat-lying strata dip a little towards the south-east, and in other places towards the north-east. This diversity and opposition of dip or declivity is occasioned by the waving of the strata up and down, which is a very common incident where the strata lie very flat, or nearly level with the horizon. There is to be seen in a quarry about a quarter of a mile above Roslin, and also near Auchindinny, upon the north side of the river, a regular continuous seam of coal, only about one or one and a half inch thick, with very strong thick beds of post stone above it; and I know that there are several thick seams of coal both above and below this thin one, some of which are now working.

There are also a variety of strata lying in various positions between Auchindinny and Penny-

cuick. About two hundred yards above Auchindinny bridge, in the bed of the river, we see the vertical and the horizontal strata in the same place, the edge metals occupying the north, and the flat ones the south side of the bed of the river. This spot deserves the examination of the curious, as it determines the place and manner of their coming in contact in this part of the country.

Some of the foundations of the cotton mill at Pennycuick, and of the water courses, are cut pretty deep in horizontal coal metals, where they have cut through one regular seam or stratum of coal, about twelve or fourteen inches thick, which is to be seen betwixt the east end of the highest building and the bed of the river.

There are a variety of instructive particulars relating to this subject in the lands of Pennycuick, between the village of Pennycuick and the lands of Newhall: And there are various sections of the flat, and likewise of the edge-coal metals in the river, and in the rivulets in the lands of Newhall and Carlops. The horizontal coal strata lie so very flat in this place, and especially in the farm of Carlops, that the coal seams frequently wave up and down, which occasions several gently swelling ridges and troughs, or elevations and depressions, of the horizontal stretch of the coal and the other strata. This incident is known with

with certainty, as some of the flat coals have been worked in that farm, where the strata were found thus waving up and down.

It is remarkable, that both the edge and the flat coals, with their several concomitant strata, preserve their parallelism, and the true line of bearing from the sea, until they reach the lands of Carlups, and there the true line of bearing of the coal metals ends, and they turn away almost in a right angle towards the south-east, instead of the south-west direction, which was the former line of bearing from the sea to this place.

The edge-coal, and all its concomitant strata, appear, and really are in the utmost disorder and confusion imaginable, when they arrive at the extremity of the true line of bearing in the lands of Carlups, and they are dwindled away almost to nothing, the thickest of the seams of coal being hardly so many inches as they should be feet thick.

This disorder and diminution is occasioned by this being the out-skirts of the coal-field; and this confusion of the strata is to be seen distinctly in the banks of the river below the bridge of Carlups.

There are abundance of horizontal strata to be seen in the bed of the river South Esk, upon the east and south side of the town of Dalkeith, betwixt the Duke of Buccleugh's and the Marquis
of

of Lothian's parks. These strata slope with various degrees of declivity towards the north-west, and in some places they dip towards the north, and in other places towards the west.

There is also a variety of horizontal strata, and considerable sections of them upon both sides of this river, between Newbattle and Dalhousie; and about a quarter of a mile below Dalhousie bridge, there are some irregular discontinuous imperfect seams of coal. The discontinuity of some irregular beds of coal is an incident which is frequently met with.

Many rocks and strata are to be seen in the main branch of the river between Dalhousie and Temple, all of them lying in a horizontal position, with various degrees of declivity.

The neighbourhood of Temple is one of the happiest walks imaginable for the student of the strata of coal. He will there meet with various sections of seams of coal, and of their concomitant strata, appearing fair and regular. It is but rarely that we meet with a more complete and regular section of the strata of coal than the one to be seen close by the Temple mill, and not much above a hundred yards below the church. This is a fair and clean horizontal section, cut nearly perpendicular, and pretty high, in which there are at least four different seams of coal distinctly seen dipping a very little towards the
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N. N. E. The strata in the neighbourhood of Temple lie remarkably flat. About a mile above Temple church, the south branch of the river runs upon the face of a hard stratum of rock for more than a hundred yards in our sight, as upon a smooth pavement, and we see it running upon the face of the same stone below the church. There are several seams of coal to be seen in this branch of the river above Temple church, dipping mostly north, though sometimes the declivity changes, and the strata are found to dip towards the N. W. and also towards the N. E. This variety of declivity is commonly met with among horizontal strata, especially those of the coal metals. It is occasioned by the waving and wheeling of the horizontal strata.

The north branch of this river is well worth the inspection of the curious.

About a hundred yards above the bridge, two pretty thick seams of coal appear, and there are various sections of the coals and coal metals to be seen in several places for more than two miles up the river, some of which have been and are now working.

The Salisbury Craigs, near Edinburgh, are well worth the examination of the mineral student. The thick bed of rock at Salisbury Craigs, which was quarried some time ago, is a stratum of basalt, which is easily known by examining the

the quality of the stone; and the fact may be further evinced by tracing the stratum to the south side of Arthur's Seat, where the same individual bed of stone will be found regularly formed into columnar basaltes; the columns are distinct, and of considerable length and magnitude. When the examiner has made himself master of the stretch, bearing, and declivity of this particular stratum, he may then proceed to investigate the rest of the strata of Arthur's Seat, which is not an easy task for a beginner, the whole hill being chiefly composed of different irregular thick strata of basaltine rocks, which vary in thickness considerably in different places; a circumstance common to basaltes; and, therefore, on account of the difficulty of investigation, I would not advise the mineral student to begin a survey of the strata of this mountain, until he is pretty well advanced in the knowledge of the natural history of strata in general.

When he comes to examine these rocks, he will observe, that the whole hill is not entirely composed of basaltes. There are also thin strata of various species to be found among those rocks. For instance, several beds of free-stone have been quarried deep down upon the south side of Salisbury Craigs; and there are regular thin strata of several kinds to be seen immediately above
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and below the thick stratum of rock which is properly called Salisbury Craigs.

There is a pretty good section of various thin strata upon the south side of the Water of Leith, immediately below the mills, and there are a great number of thin strata to be seen in the bed of the river, all the way down below the Mineral Well. These strata appear pretty fair and regular, dipping with an easy slope towards the N. W. or W. N. W.; but the circumstance which is best worth the inspection of the student in this place, is a couple of whin dykes which cut the strata asunder. These two dykes are to be seen in the bed of the river, one of them near the Mineral Well, and the other a little higher up. They run quite across the river, almost at right angles; and these dykes, or ridges of stone, are the more remarkable, that these sort of troubles, or interruptions of the regularity of the strata, are but seldom met with in the Lothians, though common enough in other places.

But although whin dykes are not so commonly found in the Lothian coalleries as they are in some other coal-fields, yet the Lothians are not exempted from them. A large whin dyke passes through the coals, &c. a little below Niddry, where it crosses almost at right angles to the bearing of the strata. Another, still larger,
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is to be seen emerging out of the sea at Cockenzie, where it forms the north side of the little harbour, and then runs end-ways through the country.— And, in like manner, several other very large whin dykes are to be seen as you go farther to the N. E. along the shore, some of which form considerable ridges of rock as they pass through the country, which appear in many places high above the surface of the ground; and all of them are distinctly seen to cut through the coal metals in a line nearly right across the bearing of the strata.

It may not be improper, however, to remark, that there is one circumstance appertaining to the two whin dykes in the Water of Leith, that is not common to every one of the kind, which is, that each of these two is both a dyke and a slip; that is, the strata, which are cut asunder by the dyke, are not here found upon the same level on both sides of the dyke, which happens in most (though not in all) others of the same kind. These dykes, which throw the strata off the ordinary level, may properly enough be called slip-dykes.

There are a great variety of strata further up in the river Leith, about Slateford, Collington, Currie, and still farther up, and some pretty good sections.

There

There are various sections of the strata to be seen upon the banks and in the bed of the river Almond, particularly all the way between the sea and Cramond bridge, and farther up, all the way till within three or four miles from Calder.

There are good sections of the strata in the branch of that river which runs upon the south side of Calder, above the bridge, and especially above the house of Calderhall, and still farther up towards the moors. About half a mile below the south bridge of Calder, there crosses the river a thick stratum of coarse limestone, which contains some lead ore in grains and flowers, blended in the composition of the stone; but it does not appear in such quantity as to be worth working.

A considerable variety of strata are to be seen in the north branches of the river Almond, above Calder, and among them several coals, some of which have been worked; and there are some pretty good sections of coals, and their concomitant strata, in the branch of that river called Breich.

There is a fine section of two seams of coal, and of the strata accompanying them, to be seen in the free-stone quarry upon the east side of the river near Cranston.

The county of Fife is a fertile field for the amusement and instruction of such as wish to im-

prove in the knowledge of the natural history of the coal country, as almost all the rivulets in the county exhibit sections of seams of coal and their concomitant strata.

There are many sections of the coal metals to be seen upon both sides of the Forth, above and below Inchkeith.

The river Clyde, and its numerous branches on both sides, cut and intersect an extensive coal country, where a variety of fine sections are to be seen; and there are magnificent sections and romantic scenes in the channel of that river, between Hamilton and Carstairs.

Almost the whole county of Ayr abounds in coal, and it also abounds in scenes proper for the amusement of the mineral student. All the rivers, and almost all the rivulets of that country, exhibit fine sections of the strata, and particularly the river Ayr and its several branches.

I have now pointed out a sufficient number of local examples of sections, and of regular strata, and the places where they are to be found in the Lothians, &c. When once a spirit of enquiry about these matters is excited among young gentlemen, they will then be forward to look
out

out for more, and they will easily find as many as they can wish for.

The coal fields, or coal countries, are not the only places where we meet with regular strata. There are, besides the coal-fields, numberless fine and regular sections of them to be found in the rivers, and especially upon the shores of the ocean, all round the island of Britain, and particularly round the Highlands and north of Scotland; and of all places in the Highlands and north of Scotland, Caithness is the most remarkable. The sea coast of Caithness is singular for magnificent, extensive and lofty sections of remarkably thin and uncommonly regular strata; and though the strata upon the shores in some parts of Galloway, particularly in the stewartry of Kircudbright, are regular and lofty, yet they are not generally so thin as those of Caithness.

In both these places, especially upon the south-east coast of Caithness, and in the parish of Colvend in Galloway, the student has an opportunity of viewing and contemplating regular strata for miles in length, where he will not only see beds of stone, which exhibit a great variety as to thickness, colour, and other external appearances, lying *stratum super stratum*, as he advances along shore, with various degrees of slope or declivity; but he will also have an opportunity of viewing and of investigating a great many of the troubles, breaks,

breaks, and irregularities of the strata, such as dykes, slips, shakes, &c.

These extensive and lofty sections, or cliffs, may be called the anatomy of some parts of the mineral kingdom, where the student can see some parts of his subject dissected and laid open for his examination.

Among a great variety of other particulars to be seen in the two districts under review, are a great number of caves or caverns of different magnitude and length. Some of these caves are exceeding wide and high, others of them are of middling and of lesser dimensions. Again, some of them are only a large and spacious cavern, at and near the mouth, but are of no longitudinal extent, that is, do not push far in, and others of them push a great way in under the land. It is a remarkable fact, which, in my opinion, deserves to be noted, that each of these caves or caverns is a real mineral vein, and the most of them, if not all, are real slips in the strata, such as were described above in the coal metals. The most of these are what is called by miners *rake veins*,—by naturalists, perpendicular mineral fissures; and it is a fact which I have seen, and deserves farther to be noted, that a considerable number of these veins in both places, but most at Colvend, contain copper ore, which may in time become valuable.

Many

Many of the caves upon the sea shores of Caithness, are the common lying-in hospitals for the seals, where they go to bring forth their young, and to suckle them until they are fit to swim, and many of them, both young and old, are taken in these caves by the country people, who surprize them at night with lights, and knock them on the head, and sometimes these people are hurt by the seals, who make a desperate resistance, and many of them escape by mere force.

The cliffs, in many parts of the West Highlands and Isles, resemble very much the shores of Caithness and Galloway, and almost every considerable rivulet in several parts of the Highlands has cut through many regular and curious sections of the strata, and many of the Highland rocky mountains exhibit some prodigious cliffs or sections of immense height and magnitude. In the Highlands of Scotland the mineral student will meet with abundance and variety of amusement and instruction, that can hardly be met with any where else.

Though the examples of stratification I have here pointed out, may be deemed a digression, when treating of the natural history of coal, I, however, think these a piece of necessary information to a mineral student.

When

When young gentlemen descend into the rivers and glens, and other places in the coal country, or elsewhere, to improve themselves in the knowledge of the strata, and come to examine various sections, it may be proper for me to drop a few hints about the different sorts of sections of the strata, and how they are to distinguish one section from another. There appear to be three different sorts of sections of the strata: 1st, *The level or parallel section*;—2d, *The right-angled section*;—and 3d, *The oblique, or diagonal section*.

1st, The level section is one that runs in a line parallel to the bearing of the strata. When we are viewing one of these parallel sections, we see the edges of the several strata lying flat or level before us; and when we face such a section at right angles, so as the right and left hand are equally near the face of the rock, the declivity then is in a right line from the eye across the strata, and the dip is in a right line either down towards the foot, or away from the eye; and if the strata lie very flat, it may sometimes be difficult to know which way the strata decline in such a section, as perhaps no sensible slope appears any way.

2d, The right-angled section is one that is cut in a line right across the bearing of the strata, and parallel to the declivity, or in other words, this section is in a right line from crop to dip.

When

When we face one of these sections, so as to bring the right and left hand equally near to it, then a line drawn straight forward from the eye is a dead level line, which runs parallel to the bearing of the strata. This right-angled section is more entertaining and instructive than the former, for in this we not only see the various kinds of strata disposed in a regular order, *stratum super stratum*, for our examination, but we also see the degree of slope or declivity of the several strata.

In this section we see the one side or edge of each stratum dipping downwards quite out of our sight, and the other side or edge rising up quite to the day, or to the clay or other cover, if the superficies of the strata happen to be covered in that place.

3d, The oblique, or diagonal section, is more difficult to be described or explained with precision than either of the former two, because it may be so various, or may run in so many diagonal directions or collateral lines across the bearing and declivity; and, therefore, I shall only in general observe, that some of these sections may approach pretty near to the parallel or horizontal section, and yet have a small degree of slope or obliquity, and others may approach pretty near to the right angled section, and yet not be quite parallel to the declivity, or be in a right line from crop to dip, though near it.

It

It is to be supposed, that there are a greater number of these oblique or collateral sections than there are of the parallel or right angled, because all those that are cut in any possible acute or obtuse angle or line between the other two, must come under this denomination or description.

With respect to the first, that is the *parallel section*, it may be impracticable to determine the degree of slope or declivity of the strata, even with an instrument, because you only see the edges of the several beds of stone, or others, facing you in level or parallel lines. If it be a fair, regular, and uniform section; perhaps the best rule then for judging of the degree of declivity, especially if the slope is right away from the eye, is to consider the position of the face of the section. If it stands nearly perpendicular, we may generally conclude that the position of the strata is nearly horizontal. If the face of the section leans back with a considerable slope, and the foot of the rock advances forward towards your foot, you may then conclude that the strata decline away from you with a considerable or proportionable degree of slope, as the several transverse fissures which occasion such regular sections, are generally cut across at right angles to the bed of the strata. If the declivity lean forward towards the eye, you will then see the
edges

edges of the strata hang down towards you, and then you can judge of the degree of slope. When the slope is down towards you, such sections generally overhang a little.

With respect to the second, that is a *right-angled section*, you can take the degree of the declivity of the strata in it at once, as a line stretched from crop to dip along the face of any individual stratum in the section, will be exactly parallel to the slope or declivity of the strata.

But it cannot so easily be determined what is the degree of slope, or declivity of the third, or *diagonal section*, because the section itself is cut in a collateral line, and it cannot be determined at once without examination how far this line is upon one side or other of the line of bearing, or upon one side or other of the line of declivity, which two lines, that is the bearing and declivity, form a right-angle.

All that I have yet advanced on this subject, relates only to what may be called regularly disposed strata, and to such accidents as locally disturb and break through that regularity.

But it may be proper to enquire whether or not all the rocks which compose the superficies of our globe are regularly stratified, or if there are certain species, classes, or arrangements of rocks which are always found stratified, and others that are not.

With respect to stratification, the materials which compose the superficies of the globe, may be divided into three classes: 1st, Such as are always, or at least generally found regularly stratified; 2^d, Such as are partly and imperfectly stratified; and 3^d, Such as are seldom found stratified at all.

Of the first sort are all the coal metals, most of the argillaceous strata, the generality of limestones, and many of the indurated mountain rocks of several species.

Of the second sort are many of the mountain limestones, which are extremely irregular, both as to the thickness of the stratum, and as to the continuity of it in the line of bearing; and many of the basaltine rocks so frequently met with in the Lothians, Fife, and other parts of Scotland, are likewise very irregular in thickness and in continuity upon the line of bearing. Both of these are so irregular in this respect, that sometimes they swell out to an enormous thickness, and a little way forward, upon the longitudinal line of bearing, they are found dwindled away to almost nothing, and two or three hundred yards farther forward, still upon the same line, the same individual stratum will swell out again to various degrees of thickness. Many of the mountain limestones exhibit the same irregularity.

Of

Of the third sort are many mountains of granite in the Highlands of Scotland, and many other places. It is no uncommon thing to see granite rocks so perfectly free from any marks of stratification, that there is no difference between a small solid mass of that stone and a mountain, except only in magnitude, the whole mountain being one prodigious mass of solid stone, without any division of strata.

There are also some other rocks besides the granite mountains which have very little appearance of stratification. Such, for instance, are some little hills of mountain limestone, which we meet with in the Highlands and other places, and likewise little hills of basaltes, which we see forming little islands in the frith of Forth, in many parts of the Lothians, Fife, and other parts of Scotland.

Many of the rocks which may be called regularly stratified, have in some places very great imperfections in the strata.

Some of these are imperfect in point of continuity, and such either fail entirely, and are lost in the longitudinal line of bearing, or else turn thinner or worse in quality in the same line.

Others are found to resemble a wedge, and such a stratum will be found pretty thick at the surface, but as it goes down towards the dip, it wears

wears thinner and thinner until it comes to an edge, when it soon ends in nothing.

Some again are found of a good thickness below, which wear thin as we come upwards, and at last come to a thin edge, and end in nothing before they come up to the surface.

Some particular strata are found irregular, wear thicker and thinner, and are sometimes entirely lost in advancing upon the longitudinal line of bearing, as well as in going down upon the line of declivity.

Again, there are some strata so imperfect, that they resemble a double wedge, that is, such strata are found irregular, and fail in continuity both ways, and do not stretch so far as the regular strata which accompany them. These are found to be thick in the middle, and to wear thinner and thinner, and end in nothing, as we advance both ways upon the line of bearing.— There are many other instances of imperfect stratification too tedious to be investigated here.

I shall now enquire whether a stratum of coal found but thin at the crop or surface of the ground, will grow to be a thick seam farther down towards the dip?

A seam of coal is found fully as thick in the superficies of the strata as it is farther down. When once a seam of coal is discovered at or
near

near the surface of the ground, if it appears when discovered, or is afterwards by trials brought fairly between regular roof and pavement, it may be taken for granted that it is then at its full thickness, and would not increase, though you should sink twenty fathoms in it.

There are particular instances of coals being thicker below than above, and also of their being thicker above than below; but, in general, they are at full thickness when found between roof and pavement.

In a considerable coal-field, there are a great number and variety of seams of coal cut through in bringing up levels, in driving cross-cut mines, and in sinking pits. Some of these seams of coal are of very considerable thickness, and others of them are very thin, perhaps not above two or three inches. And again, many of them are of all the medium thicknesses between the two extremes of the thickest and the thinnest.

Now all these various seams are generally found to be very near the same thickness above as they are below, when once they are found between solid and regular roof and pavement; and this is necessary in the nature of things, because then the seam of coal is a regular stratum among regular strata, which are disposed above and below it, and, therefore, it should, and in fact it does keep its station full as regularly as any of those found

found placed above and below it, both in the longitudinal line of bearing, and from crop to dip in the line of declivity.

In short, when a seam, whether it be thin or thick, is once found fairly bedded betwixt regular roof and pavement, and is perfectly clean and free from hitches, or any other troubles, it is then at its full thickness.

Perhaps these assertions may seem to intimate, that all seams of coal are invariably regular in thickness, both in the line of bearing, and likewise in the line of declivity; but I would not wish what I have said to be understood in that light. True it is, that in common experience we find a seam of coal pretty regular and uniform in thickness when we have it fairly betwixt roof and pavement, and this in general will hold good, and may be considered in practice as a fixed principle; nevertheless, there are some circumstances and accidents which alter the case, and occasion the seam to vary considerably in thickness.

However, the maxim will hold good in general, notwithstanding these accidents. A seam of coal is frequently found thicker upon one side of a slip than the other, and likewise upon one side than the other of a great dyke. The same may be observed of some of the great shakes and gashes. The same individual seam
of

of coal seldom preserves invariably the same uniform thickness to the extent of four or five miles forward upon the line of bearing, though it may pretty nearly within a more limited field of only a mile or two. Great variations in the dip and rise of a coal frequently affect the thickness of the seam, and such changes in the degree of dip or declivity often occur as we advance upon the line of bearing, and when a seam of coal falls suddenly from higher to much lower ground, the thickness of the seam is frequently altered.

Some coals are much more regular and uniform in thickness than others. I have seen many seams continue perfectly regular and equal in thickness for a considerable extent every way, and I have seen other seams so exceedingly variable, that you could not depend upon finding the coal equally thick for twenty yards together in any part of the field, and in some seams you cannot find ten yards of it of equal thickness.

The common accidents which we meet with in working coals, such as dykes, slips, gashes, shakes, &c. frequently occasion their varying in thickness.

Sometimes the roof falls down for a certain space below its ordinary level, and presses the coal, or squeezes it much thinner, especially in the middle of that space. These accidents of the
roof

roof pressing down nearer the pavement than it should be, and squeezing the coal below its ordinary thickness, are of less and greater dimensions. Some of them are not above two or three feet in diameter. These lesser ones are like a wart or small protuberance on the under side of the stratum, which is the immediate roof of the coal, and this protuberance sinks down into the upper side of the seam of coal like the bottom of a great pot. These protuberances are called by Scotch colliers a *bonnet case*, and a *pot arse*.

But all these accidents are not of such small dimensions as the bonnet case. Some of them are not only two or three feet, but two or three yards diameter, and sometimes even up to thirty or forty yards, and more. I observed that the small ones thrust down suddenly into the upper side of the bed of coal like the bottom of a great pit; but, on the contrary, the large ones generally press down gradually with a gentle swell.

These troubles sometimes squeeze out one third, and at other times one half or more of the thickness of the coal. They are frequently of a roundish figure, and they squeeze out the coal thinnest in the middle of the trouble, which rises gradually higher as it extends from the center, until the roof comes to its ordinary level, and the coal comes to its ordinary thickness at the outskirts.

But

But the principal and greatest of all the causes of the variation of the thickness of the coal happens when the seam approaches the extremity of the coal country, where foreign strata commence of a quite different quality from the coal metals. The coal metals, and especially the coal seams, always wear thinner and thinner as they approach the outskirts of the coal country, as it may be called, that is the out boundaries of the coals and coal metals. In this case, I have seen seams of five or six feet thick dwindled to so many inches, and even to less than so many inches at the extremity, where the coal metals ended entirely, and other different classes of strata commenced.

The vulgar error of the *craw coal*, as it is called in Scotland, frequently proves a dangerous error, and, therefore, I will explain the matter in order to give a caveat against the pernicious consequences of that notion.

What is meant by the *craw coal*, is the crop coal, or upmost seam of coal in the field, which is always supposed to be a thin one.

The notion of the *craw coal* originated from the false supposition, that in all places where coal is found; a thin seam is upmost, and that when once a thin seam is found, you are sure to find a

thick seam at a moderate depth below the thin one, or *craw coal*. This, it is acknowledged, may sometimes happen, and indeed it frequently does happen. We know it by experience, and therefore it cannot be denied; at the same time nothing can be more absurd than to assert that it always happens so. That notion is the child of ignorance and fraud. The ignorant imagine the assertion to be true, because it sounds like something they wish to be true. It seems to give them a *clue* to lead them at once through depths of knowledge which they have not yet explored, and they either cannot or will not take the trouble to examine the truth of the position, and the crafty make use of the notion to lead the unwary to throw away expence upon a bad subject.

By observation and real experience, we know that nothing in the world can be more promiscuous and uncertain than the way we find the thick and thin seams of coal blended through one another in a coal-field; and this fact of their being promiscuously blended together we know with absolute certainty, by cutting through a great number and variety of them in some extensive coal-fields, where we as often find a thick seam upmost as a thin one, and we as often find a thin seam below as above a thick one.

The truth is, we can form no true notion of their disposition and order until we have either
cut

cut through them, or have some other opportunity of seeing how they are disposed one above another; and yet the notion of the craw coal still prevails in many parts of Scotland; for I have often heard those who were making trials for coal say, with a tone of assurance, that they were now certain of coming to a good seam a few fathoms deeper, this being an infallible symptom of a thicker and better seam being near.

But a man of real knowledge and extensive observation, will frankly declare that he knows nothing about the matter until experience comes in for his guide. Ignorance and conceit, which are near of kin, and often go hand in hand, sometimes favour us with many rash and unphilosophical assertions which experience and observation disprove.

In great coal-fields, which contain a great number of seams, we find that the thick and thin seams are mingled with so much uncertainty, that we never pretend to know which of them are above, or which are below, until we have seen them all, and then we know their order and stations very well.

I have frequently seen three or four (and sometimes more) thin seams of coal placed next to one another, neither of which were any thing near thick enough to work; and I have often seen good workable seams of sufficient thickness lying
next

next to one another, without any thin coals intervening betwixt them; and I have as often, perhaps oftener, seen the thick and thin and middling seams blended promiscuously. Indeed they are always so blended, that we know of no order or natural station, nor of any thing else relating to them, but what we come to know by experience, after we have once seen all or most of all the seams in the coal-field.

Further, it is not only the seams of coal that are thus promiscuously blended together in the coal field; the various and different coal metals are also mingled together, and with as much uncertainty, as to any rule or order of their stations, as the seams of coal.

There are in most coal-fields a multitude and surprizing variety of different kinds of strata accompanying and lying between the several seams of coal; and of this vast multitude, and variety in quality, thickness, and colour, we find the hard and soft, thick and thin, the black and white, blue and gray, red and yellow, and all the varieties of quality, thickness, and colour so promiscuously blended together, that when we are sinking pits, or driving mines through any of them, the most experienced do not know what is to come next, until they have somehow or other acquired that knowledge by former observation, that is, by
seeing

seeing the order and disposition of those strata somewhere before.

We have in our coal-pits and cross-cut mines, and in the rivers and rivulets which have cut and washed the superficies of the strata in our coal-fields, abundant ocular demonstration of the truth of the position that the coals and coal metals are promiscuously blended together, without any certain order to be depended upon as a rule or indication in practice; and moreover, the great variety of strata of different qualities and colours, hard and soft, thick and thin, which are found to be the immediate roof of the several seams of coal, even in the same field, is another convincing proof of the truth of the position, in aid of ocular demonstration, if it needed any aid.

Though there should be twenty seams of coal in the same field, it is twenty to one but they shall be found to have twenty different roofs, that is, that stratum, which is the immediate roof of one seam of coal, shall differ from the immediate roof of another seam in quality, colour, and thickness, in so much that perhaps no two out of the twenty shall be exactly alike.

The several roofs of coal may, in point of hardness, be divided into three different classes. There is such a variety of these in point of quality, colour, and thickness, that it would be exceedingly

ceedingly difficult to arrange them properly with respect to all these varieties.

I will take a cursory view of some of them in point of hardness, and will just touch at their several qualities and colours, and in doing this, I will, 1st, examine such as may be called very hard ;—2^d, Such as may be called good and firm coal roofs of middling hardness ;—3^d, Such as may be called soft roofs, but in respect to the exact thickness of the stratum, with the colour, quality, and degree of hardness, the variety is almost endless.

I. Among those which may be called very hard roofs are,

1st, Strata of basalt, commonly called whinstone. Strata of basaltic rocks are very common in many coal-fields in Scotland. There are several thick beds of this stone betwixt the different seams of coal at Borrowstounness, and one of them is the immediate roof of a seam of coal in that ground ; and there is a thin seam of coal below a bed of beautiful columnar basalt at Hillhouse limequarry, a mile south of Linlithgow. In the Bathgate hills, south of Linlithgow, there are several strata of coal and several strata of basalt blended together, *stratum super stratum*.

These instances may suffice as a proof that strata of basalt are sometimes the immediate
roof

roof and pavement of strata of coal. The several strata of basaltine rocks are always very hard, often very thick, and generally of a black or blackish grey colour. But it is proper for me to remark here, that the basaltine rocks are only known to be such by a very few naturalists. They commonly go by the general name of *whin-rocks* in most parts of Scotland and the north of England. I think it goes by the name of *cockle* among Cornish miners, and it is called *skurdy* in the north of Scotland.

Among the few gentlemen who are acquainted with basaltes, the most of them imagine that the rock should always be found formed into prismatical figures or angular columns; but this is supposing too much, for the truth is, that this rock is only found formed into columnar or other regular figures in such places where the rock was originally exposed to the influence of the external air.

As a proof of this assertion, the thick stratum of rock near Edinburgh, called Salisbury Craigs, is only formed into regular columns upon the south side of Arthur's Seat, where it was originally exposed to the atmospherical influence.

Another proof of the above assertion will be found in the stratum of basaltes, which is formed into small and beautiful columns at Hillhouse lime-quarry near Linlithgow, as the same individual

vidual stratum will be found not formed at all in several places at a small distance from that quarry.

The basaltine rock is to be judged of and denominated from its quality and colour and component parts, and not only from the figure it sometimes assumes, which is merely accidental, arising from situation more than from the quality of the stone. This rock is very common in the coal countries, and in many other parts of Scotland, and it is frequently found formed into glebous, spherical, and other figures, as well as the columnar; but always where it now is, and we have good reason to suppose that it always was exposed to the external air.

Wherever we trace a stratum of basaltine under the cover of other incumbent rocks, it is not then formed into any regular figure. Wherever we cut through it in sinking coal-pits, we do not find it regularly formed. Wherever the face of a regularly formed basaltine rock is quarried away until it goes under other incumbent rocks, we soon lose the angular figures, and an uniform face of a rock comes in without the least appearance of a prismatical glebous, or any other regular figure.

2d, Lime-stone may be reckoned among the very hard roofs of coal. Strata of lime-stone of various thickness, quality, and colour are very common

common in coal-fields. Sometimes the stratum of lime is the immediate roof of the coal, and sometimes there is a thin argillaceous stratum or following clod a foot thick, less or more, found betwixt the stratum of lime and the stratum of coal.

There are several beds of lime-stone in the coal-field of Gilmerton, near Edinburgh, and some of them are very good, and of considerable thickness.

At Blackburn, in West Lothian, a stratum of lime-stone, of six or seven feet thick, is the immediate roof of a good seam of fat caking coal, which seam is also about five or six feet thick.

At Carlops, and at Spittlehaugh in Tweeddale, they have a seam of coal immediately below their lime quarries, which they work out to burn the stone.

I have seen lime immediately above coal in a great many places; but these are sufficient instances in point, as the fact is commonly known.

3d, Some of the post free-stones prove very hard roofs of coal. What is commonly called post stone, is a thick and solid stratum of free-stone, out of which blocks or pillars of any size and figure may be cut out by a skilful quarrier. Thick strata of post stone are frequently found to be the immediate roof of seams of coal, without

the intervention of a following clod, or any stratum whatever between them, and sometimes with a following clod, or a thin argillaceous stratum betwixt the coal and the main roof of post stone; and the post roof is frequently rendered very hard, by being intersected with foul ribs, or mixed throughout with ferruginous matter, of a species of iron or pyrites.

4th, Thinner strata of freestone are commonly found in most of coal-fields to be the immediate roof of coal; and some of these, as well as the post stones, are rendered very hard by admixtures of ferruginous or sulphureous matter.

5th, What is called a *dogger band* by Scotch colliers, is very frequently found to be the immediate roof of coal, and these are very hard.

Some call strata of iron-stone *dogger bands*, and the ball iron-stone they call *doggers*, and they also call masses of the pyrites *doggers* in many of the Scotch collieries; but besides the strata of iron-stone, there is also another species of coal roof frequently met with, which is called a *dogger band*. This *dogger band* is an imperfect stone, composed of several heterogeneous mixtures, among which pyrites bears a considerable proportion, which so effectually binds and connects the whole together, that it is sometimes very difficult to break through it. This species of *dogger band* is sometimes much thicker

thicker than the strata of iron-stone, though not always. Both the sorts are well known to be very hard, and to be frequently found immediately above the coal.

6th, There are in many coal-fields several strata of whin-stone, properly so called, which is not basalt. Some of these are of considerable thickness, and others not above two or three feet thick; and they are of various colours, such as black, a blackish and lighter grey, brown, red, &c. These strata of whin-stone are always very hard, and they are frequently the immediate roof of coal,

II. There are a great many good and substantial roofs of coal, which yet are kindly to work, and only of middling hardness. Among these I will reckon,

1st, Post-stone of a kindly quality, which is not impregnated with ferruginous matter, or any other heterogeneous mixture which hardens the stone too much, and makes it cross and difficult to be cut.

2d, Regular strata of free-stone of various colours, textures, and degrees of thickness; but none of which are so thick as to deserve to be called post-stone.

The thinner strata of sand-stone, that is of free-stone, are perhaps the most numerous of all

all stones in most of coal-fields, and they are so frequently found to be the immediate roof of coal, that it would be superfluous to say any more about them; only it may be noted, that some of these regular strata of clean and pure sand-stones, are not above three or four feet thick, and others not above three or four inches; and they are commonly found of all degrees of the medium thickness between these two extremes; and these thin and middling strata of free-stone make good coal roofs easily cut through in sinking; and they are easily quarried, and make excellent rubble stones for building, and some of the thickest of them produce good cutting stones for ribbets, &c. though I do not think they deserve to be called post-stone until they exceed three or four feet thick.

3d, Grey bands, or grey coloured free-stone bands, are likewise commonly found to be the immediate roof of many seams of coal, and these may be reckoned among those of middling hardness. These grey bands, or grey thin strata of imperfect free-stone, are very numerous in all coal-fields, and there are generally a great number of them arranged together in the same place, lying immediately above one another; and they are frequently found of all degrees of thickness, from one inch up to twenty inches, though the most common thickness is from two to six inches. These thin grey strata are called by Scotch colliers

liers *grey fakes* as well as grey bands. They are often found moderately hard, and of a strong texture, so as frequently to make good flags and covers for sewers. When there is a considerable number of these together, they commonly make a very good and safe coal roof, as they generally have a considerable degree of strength and cohesion, especially when the ingredients in the composition of the stone, which give it the blackish or grey cast, partake of the nature of the coal; but when the black admixture partakes of the blaes, or black tilly argillaceous matter, then the grey bands are more weak and fragile.

4th, Hard, strong, and well stratified blaes may be reckoned among the coal roofs of moderate strength and hardness. Strata of blaes, or bleas, are very common and exceeding numerous in coal countries. They are always black, or of a bluish black or a black grey colour, and there is nothing more commonly the immediate roof of coal. There is in most coal-fields a great variety of blaes, especially in respect of strength and hardness; but in this division of middling coal roofs, I only point at such as are pretty strong and hard. Some of the strong and hard blaes are perfectly black, or of a greyish black, and some of these strata of different shades of the black colour, are pretty thick, and others are pretty thin. I say pretty thick, for it is not
common

common to find strata of good and strong blaes much above a foot and a half thick; but they are commonly found of all degrees of thickness, from about a foot and a half down to two or three inches and less; and the most common medium of the strata of the best blae roofs is from one foot down to three or four inches thick.

Some of this sort of blaes is so strong as to make a very good and a very safe coal roof, but it is rare to find any of it so hard as not to be easily cut through in sinking. All blaes seem to have a considerable quantity of a black argillaceous matter in the composition of the stone, and these strong blaes appear to contain a considerable quantity of sand, and they frequently contain a considerable portion of an inflammable oil, and sometimes they partake of the real coal itself in such quantity as to be sometimes visibly seen.

In some places the thinnest of these strata are found to be the immediate coal roof, and in other places the thickest; and again, in other different places, those of all the degrees of medium thickness.

There is as great a variety in the quantity of these blaes found together immediately above different coals as there is in the thickness of the particular strata. In some pits we do not find above five or six inches of blaes immediately upon the
the

the coal; in other pits, we find five or six fathoms upon the coal, and in some particular places even much more than five or six fathoms, and it is very common to find the blae roofs of all the medium thicknesses.

5th, Whitish and ash-coloured argillaceous strata, of middling strength and thickness, are in many places found to be the immediate roof of coal.

Some of these light coloured argillaceous coal roofs are pretty thick, others of them are thin and of middling thickness, like all the other coal roofs of pretty equal strength and hardness. I have seen some of these up to two feet thick, and I have seen others of them not above two inches thick, and they are commonly found of every medium thickness between these two. There are a great many coal roofs of this colour, and much of the same quality, which are very tender, fragile, and dangerous. At the same time, many of them prove very good roofs, owing either to some particular ingredient in the composition, or to a more perfect contexture and formation of the strata.

6th, Streaked coal roofs of middling strength and hardness. These streaked roofs are of two sorts. *First*, Such as are composed chiefly of sand, with a very small mixture of clay and blaes; and *second*, Such as are composed chiefly of clay or blaes, with a very small mixture of sand.—

Some

Some of these exhibit larger, and others smaller streaks or ribs. I have frequently seen some of these stones so finely streaked as to resemble the most beautiful striped cotton stuffs.

The strips or streaks lie all of them exactly parallel to one another, and exactly parallel to the bed of the stone, and the strips always spread out the whole breadth of the stratum. The colour of these strips is various in different strata. I have seen some of the strips nearly black and white, others white and red, and yellow and red. In some strata the strips appear of a lighter and a darker grey colour. In short, these strips in different strata appear of various colours, and of various shades of those colours.

Some of the finely striped stones exhibit streaks less than a quarter of an inch. It is very common to see strips about a quarter, and between that and three quarters of an inch; but in these finely stratified and finely striped stones, it is not common to find streaks of a full inch thick, without some different shade in one side or other of the strip. The stratification of these striped stones is generally as perfect and regular as can be imagined.

The second sort of these striped coal roofs, that is, such as are chiefly composed of blaes, with a less mixture of sand, differ but little from the first in appearance; only the colours are not always

ways so bright, nor the strips so fine, nor is the roof quite so hard as the sand-stone striped roof.

III. Soft coal roofs, of which there are a very great number and variety, with respect to quality, colour, and thickness. I will point out a few of them, and I shall begin with such as are of a black, a bluish black, and a black grey colour. Of these some are regularly stratified, others are imperfectly stratified, and some of them not stratified at all. All these soft black and blackish coal roofs are by the Scotch colliers, and those of the north of England, called by the general name of *blae*, or till.

1st, I will first take notice of such as are regularly stratified. Some of the stratified blae roofs are formed of pretty thick strata, others of them are formed of thin strata, and many of strata of middling thickness. There are arrangements or classes of regularly stratified blaes found as the immediate roof of different coals of a great variety of thickness, from three or four inches up to a good many fathoms; but of the particular thickness of each stratum of those I call regularly stratified, I have seldom seen any one of them much above a foot and a half, or at most two feet thick; but I have frequently seen great numbers of them not above two or three inches, and some of them not much above one inch thick,

even where there was in all a considerable thickness of blaes, consisting of a great number of strata, thick and thin, arranged together. Some of these tender roofs of regularly stratified blaes have an oily appearance upon the outside, and through all the fissures and joints of the strata, that is, they appear smooth and glossy, and are very slippery to the touch. Others of them have nothing of this; but whether oily or not, these soft blaes make but a bad or indifferent roof at best, as they are always tender, weak, and fragile.

2d, The second sort of soft coal roof which I am to mention is blaes, which is only stratified in part, or imperfectly stratified. This sort of roof is in every respect the same in quality and colour as the last, the only distinguishable difference between them being in the different degrees of stratification. This sort appears clumsily stratified, and the strata or beds of it are not perfect, but unequal and lumpish, which makes it a bad and dangerous roof, as the inequality and various joints of the strata occasion their falling down in large masses or lumps when the coal is wasted from under it. Some of these irregular strata of blaes appear in thick, and others in thin and middling beds; and some of these, as well as the last mentioned, have a greasy or oily smoothness, and they are called by Scots colliers *creefby blaes*, that is, greasy blaes. This oily smoothness makes these

these irregular strata particularly troublesome and dangerous in a coal roof, as these being full of joints and natural divisions, which run in all directions, the oil runs through all the joints, and occasions this sort of blaes to slip and fall out so soon as the coal is worked away from under it.

Some of these glossy greasy blaes have such a quantity of the natural oil as to make them flame a little in the fire, and there is in some places a considerable quantity of the hard stratified blaes mentioned above, which will not only flame in a fire, but some of it will actually burn when fire is set to it, though it will not consume. There is a species of pretty hard stratified blaes at Pitfirran in Fifeshire, which burns so well, that if a small fire is once kindled at one corner of a hillock, it will burn throughout; but it is no less in bulk after than before it was burnt, nor does it produce any ashes. This blae is of a pretty good black colour before it is burnt, but the fire turns it to a pale red, in which it is so far from consuming, that it acquires a considerable degree of hardness in the fire, which makes it pretty good stuff for roads. It is remarkably good for horse and foot paths, but not so proper for such roads as are constantly occupied by heavy wheel carriages. It appears pretty evident, that this blae contains a portion of natural oil in the composition

composition of the stone, as it burns, but does not consume at all; for if it partook of the coal matter in such quantity as to make it inflammable, part of the coal would be seen, and moreover, part of the blae would consume, and produce some ashes, which actually is the case when a blae has such a quantity of coal in its composition as to make it in any degree inflammable; which circumstance I have frequently seen, that is, I have frequently seen a small mixture of coal in some blaes, and those blaes, when burnt, produce less or more ashes; but this sort will not burn itself, like the Pitfirran blaes, but requires a continual application of fire.

3d, Soft blaes, which are not stratified at all, that is, there is no more than one stratum or bed of this blae in the same place, without the intervention of other strata above and below it. This species of blaes is as commonly found to be the immediate roof of coal as any thing else I know, and the beds of it are found of various degrees of thickness, from two or three inches up to two or three fathoms; but whether the stratum of it be found thick or thin, the whole stratum is always one uniform mass, without any divisions into several strata. But it should be remarked, that all these unstratified beds of soft blaes are not equally of one uniform mass throughout the whole stratum. Some of these soft blaes
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are found divided into small angular masses in the stratum, and other beds of it are divided into larger angular masses or glebes; but whether these soft blaes are found glebous or uniform throughout the whole stratum, they always prove a bad and troublesome coal roof.

These black argillaceous strata of the coal-field are by many called beds of till. The uniform sort are called *dauk*, and the glebous sort are called blaes, or *lipey blaes*, by Scotch colliers. Both the uniform and the glebous soft blaes frequently contain a quantity more or less of ball iron-stone, or glebous iron-stone, though some of it contains none at all. The regular continuous strata of iron-stone are commonly found in stratified soft blaes.

There is a variety of soft coal roofs of a grey colour, and of these some are regularly stratified, and some are not.

4th, Of regularly stratified soft grey coal roofs there are several sorts. The first of these which I will take notice of is the soft grey bands or grey fekes, which have a considerable quantity of sand in the composition of the strata.

Many of these soft grey bands are as regularly stratified as any coal metals whatever.

Numbers of them are found in very thin strata, and others of middling thickness; but whether
thick

thick or thin, they are so weak and tender as to make a very bad and troublesome coal roof. Many of these grey bands look pretty well at first, but they soon fail and come down when undermined and exposed to the influence of the air; and I suppose that this is owing partly to there being too great a quantity of clay in the composition of the stone, and partly to the want of a sufficient quantity of natural cement to connect the several particles of the stone together and promote induration.

5th, Soft grey regular strata, or grey bands of an argillaceous kind, and of these there is likewise a great variety, especially as to colour and thickness. Some of these are of a dark and others of a lighter grey, and some of them exhibit pretty thick, and others middling and thin strata.—These soft grey argillaceous strata are very numerous in most coal-fields, and they are frequently found to be the immediate roof of the coal; and these, as well as the black kinds, are found in all quantities or degrees of thickness above different coals from a few inches up to several fathoms; but whether there is much or little of it together, and whether these strata are thick or thin, this sort is generally found to be a weak and fragile roof.

6th, Soft grey argillaceous bands, imperfectly stratified. These differ little or nothing from the
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the last in quality or colour, the only distinguishable difference being in the different degrees of stratification. Many of the last mentioned sort are as finely stratified as can be imagined, that is, the strata of them are generally thin and of middling thickness, and perfectly regular, finely spread out, and every part of each stratum equally thick; but on the contrary, this sort, though it has the appearance of strata, yet the stratification is but clumsy and irregular, that is, the several beds are unequal and divided by many irregular joints into unequal misshapen masses, which makes this sort a bad and troublesome coal roof, as the masses separate at the joints, and fall down when the coal is wasted from under it.

7th, Soft grey argillaceous beds of metal or coal roofs not stratified at all, and this, as well as the black sort described above in the third division of soft roofs, is of two kinds or varieties, viz. first, such as is found broken or formed in the stratum into glebes or masses; and second, such as is found in one uniform mass throughout the whole bed, without any division into masses or strata. I need not repeat that these grey soft roofs are of all degrees of thickness, from a few inches up to a great many fathoms, as well as the black. There is but very little difference between them in any respect, excepting the colour.

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But it may be proper to observe here, that ball or glebous iron-stone is frequently found in this as well as in the black unstratified blaes, and that both in the glebous and uniform beds, and that strata of iron-stone are also found in the stratified soft grey blaes.

8th, White and ash coloured soft argillaceous coal roofs, and of these there is as great a variety as of any other whatever. Of this sort of roof some are regularly stratified, some imperfectly, and others not at all. Of the whitish argillaceous roofs, some are a compound of a gritty sand and clay, others appear to be chiefly composed of pure clay, and some of a loamy clay.

I will begin with such as are regularly stratified and mixt with sand, and of this sort some strata are mixt with sharp and gritty sand, and some with softer sand. What I have said above with respect to the variety of thickness of the several strata, and of the several parcels or arrangements of those strata into general beds of various thickness, may be said of the white as well as of the black and grey argillaceous coal roofs; and, therefore, I need not repeat what has been so often said above about the regularity and various thickness of the strata, and of the accumulating arrangements or parcels of strata. I have seen many of this sort of gritty or sandy clay roof very soft, weak, and fragile.

9th,

9th, The next whitish argillaceous soft roof I shall take notice of, is such as we find regularly stratified, and of a homogeneous quality, or not mixt with sand. Some of these are very finely and perfectly stratified, and they are found of different degrees of hardness. However, in general, the most of them prove but a weak and tender coal roof. What has been so often repeated about the different thickness of the several strata, and of the different general thickness of the several roofs, is perfectly applicable here, and therefore I refer to what is said above, to save a multitude of unnecessary words, as the principal difference between these and the black and grey argillaceous coal roofs, is in the colour, in which respect they differ widely, as some of these under immediate consideration are pretty white, others of an ashen white, and some of a yellowish white colour. I shall observe here, that this sort is not all equally well stratified. There are some of these as well as of the above found in irregular strata, and with all the other imperfections and varieties mentioned before.

10th, White and ash coloured argillaceous coal roofs not stratified at all, and of this sort there is a very great variety. Sometimes we find very thick beds of white and whitish argillaceous matter in the coal-fields, and some of these, as well as of the black soft roofs, rise in glebes and

masses of different sizes, and others are uniform and homogeneous throughout the whole bed, however thick it may be; and these, as well as the black, are found of every degree of thickness, from two or three inches up to several fathoms. Some of these beds of white argillaceous marl-like matter are found to be a sandy or loamy clay, and others of them are of a pure homogeneous clay, which does not feel gritty between the fingers nor in the mouth. I have frequently taken some of these fine white clay roofs to wash my hands, and found it answer nearly as well as soap. The shades and varieties of colour in this sort are as numerous as in the last mentioned. All the clay roofs of a homogeneous uniform structure, are called *dauk* by Scots colliers, whatever be the colour of them.

The general species and the several varieties pointed at, and described above, may be considered as a pretty full selection of the most common roofs of coal; but it must only be considered as a selection, and as a very brief and imperfect account of some of them. The different strata of the coal metals found every where in different coal-fields, are so numerous, and there are so many varieties of them, that it would take a large volume to enumerate and describe them all; but I can only pretend to give a general

neral history of some of them; and therefore I shall only further observe here, that what I have said above about the coal roof is equally applicable to the pavement of the coal, as in fact we find as great a variety of different strata below different seams of coal as we do above them.

Having taken a view of the various strata which accompany coal, I would now proceed to point out the strata of the mountain rocks, that is, such other strata as are not commonly found to accompany coal, in order to distinguish them from the coal metals; but my observations upon this branch of my subject have extended to such a length, that I have thought it proper to allot to them a distinct portion of my work.—(See part III.)

All the works of God are wonderfully magnificent, numerous, and diversified. There are a thousand discoveries to be made in all parts of the creation, and a thousand improvements to be made of those discoveries. The great masters of nature, who have looked into the animal and vegetable kingdoms with a keen and comprehensive eye, have produced such discoveries and improvements as are at once an infinite benefit to society, and an honour to human nature. The mineral kingdom is a very fruitful field, but all parts of it have not yet been suitably cultivated. I can only be reckoned a common labourer in
this

this field, but I am resolved to deserve the praise of being a faithful labourer in it.

Fanciful system builders, and some learned philosophers, but of small knowledge in these matters, have made a coil about deep and extensive strata which compose the superficies of our globe, and some of them have proposed various schemes, and tried many experiments for obtaining such sections, with a view as they supposed to countenance and confirm their several systems.

I am informed from good authority, that M. de Maupertuis proposed sinking a shaft of enormous depth in Iceland, in order to determine the structure and matter of the globe at such a depth below the upper surface; but why in Iceland more than in France, England, or Germany, which abound with materials and men of skill, I am at a loss to know, unless he supposes that every individual stratum forms a zone, or rather a shell, which stretches quite round, and envelopes the whole globe, like one of the coats of an onion; and that in consequence of the figure of the earth, these surrounding strata are all of them much thinner in the neighbourhood of the poles than they would be found nearer the equatorial regions; but however plausible this theory may be, it is not true. There is in fact no such general and extensive stretch of any individual stratum,

nor

nor of any class of strata. The various classes or kinds of strata which are found in different countries and districts, are arranged together in greater or lesser patches upon the face of the globe, which shall be clearly demonstrated by a sufficient number of examples, and well authenticated facts, confirmed and illustrated by examples, are more to be depended upon than general theories founded upon suppositions which do not exist. I will save these gentlemen the trouble and expence of sinking their shaft, and will give them a section of four times the depth which they can sink; and indeed it is necessary for me, or some other in my line, to relieve them from this embarrassment, as the revenue of an empire would not be sufficient to sink a shaft to the depth M. de Maupertuis proposed, which I think was half a mile, or near three thousand feet.

Coal masters and mineral engineers will soon (perhaps too soon) find it a difficult matter to go down one half of that depth below the surface of the ground in a plain country.— It is indeed practicable to draw up coals and other mineral fossils from greater depths in a champain country, by means of several shafts sunk in stages, one below another, with a proper landing at the head of each shaft; but it will not be found an easy matter to draw up the
water

water from such great depths, unless some new kind of machinery shall be discovered, more convenient and suitable for the purpose than any we have at present.

The fire or steam engine, which is so very useful and necessary to subterraneous operations, is indeed very powerful; but such a multiplicity and enormous length of spears or pump-rods as would reach down to the depth of four or five hundred fathoms, or even to the depth of three hundred fathoms, would become a dead weight upon an engine, and every way difficult, expensive, and troublesome.

Many of our collieries in Britain are already very deep, and in a few years hence these collieries will require to be yet much deeper, otherwise the proprietors and others, as well as many of our great towns and manufactories, will sustain a very sensible loss, and, therefore, from this consideration, it is to be wished that mineral engineers would study the philosophy of engine spears, and communicate to the public the result of their enquiries and experiments.

Fir timber is light, and of a regular grain and reed, but it is of a lax texture, and comparatively weak, and so far it is unfit for a very long spear or pump-rod. It may hereafter be very material to know what timber will answer best for this purpose,

purpose, when it becomes necessary to sink our coal-pits to a much greater depth.

With respect to a grand section which our philosophers want for ascertaining the nature, quality, form, and disposition of the strata at a great depth, I will give them one ready made, not only of three thousand, but even of six thousand feet. This grand section of the strata is cut through the coal metals at Gilmerton, near Edinburgh, and the same strata are cut through at Loanhead, about two miles south-west from Gilmerton. This position requires to be explained, as it may appear mysterious to many how such a prodigious section of the strata happens to be made in these places; and in order to this explanation it is necessary to premise, that the strata at Gilmerton, &c. as has already been taken notice of, hang or decline with a slope near about the angle of forty-five from the horizon. This slope varies greatly in different parts of the field. In some places the seams of coal and other strata incline with a slope of above fifty degrees from the horizontal position. In other places not above twenty-five, and even as low as twenty; however, upon a medium, I reckon that the slope or declivity of the strata at Gilmerton is about the angle forty-five. The dip or declivity of the strata in this district is towards the south-east, and both at Gilmerton and Loanhead there is a considerable

considerable slope and fall of the surface of the ground towards the same point of the compass; and they have in both places availed themselves of this figure of the surface to bring up a level or adit from the low grounds, in order to drain their coals of the water to the depth of these levels. These level mines are driven up in a right line across the bearing of the strata; that is, supposing the longitudinal bearing of the strata trends to the south-west, the level mines are cut at right angles, with the bearing and point to the north-west. This level mine is cut in this direction across the strata for a mile, or about six thousand feet, by which there is made the grandest and most extensive section of the strata, perhaps, that is to be found in any country. There are indeed in many countries much longer adits or level mines cut from the valleys up to the mountains and higher grounds, for the purpose of draining the water from mining fields; but it rarely, or perhaps never happens, that they pierce and cut through such a multiplicity and variety of strata in these long adits as they have really cut at Gilmerton. In many places the strata lie pretty flat, and in various degrees of slope from the horizontal position. In these they may drive or cut forward a considerable number of feet or fathoms with little or no change of strata; whereas in perforating the ground with a level mine at

Gilmerton

Gilmerton, they have a continual change of strata on account of their great declivity. The number and variety actually cut through in this field is so immense, that it would fill a large book to enumerate and describe them all. They are all what is commonly called coal-metals, that is, such strata as are generally found to accompany beds of pit coal; and there are above sixty beds or strata of coal, thick and thin, cut through at Gilmerton in this noble section, among which, about twenty of them are workable, and have been worked at Gilmerton, and the neighbouring coal-fields.—The rest are thin, though regular strata of coal, generally from between two feet to about three or four inches thick, and some of them, though regular strata, not above one or two inches. The other strata of different qualities, which have been cut through in this great section, are in general such as have been pointed out above as the ordinary roof or pavement of coal. Such as, for instance, of the hard stones, they have cut thro' whin-stone, lime-stone, iron-stone, thick beds of post free-stone, middling and thinner beds of free-stone, dogger-bands, that is, hard beds of stone blended with a great quantity of pyrites and other mineral particles, which cement this stone into a hard, stubborn, obdurate mass, not easily broken or worked through; and they have cut through

a considerable variety of these several species of hard stones. They have likewise cut through a great variety of other stones not quite so hard as the few just named, such as, for instance, post free-stone of various shades of white, of yellowish white, and of greyish white colours, of middling hardness, and kindly to work ; also regular strata of free-stone of various textures, colours, and degrees of thickness, none of which, however, are so thick as to be called post-stone. Grey-bands are innumerable, which are thin bedded strata of a compound stone ; of these there is almost an infinite variety, as to colour, quality, and thickness. Of stratified blaes, or argillaceous coal-tills, there is also a prodigious variety, in respect to colour, thickness of strata, and degrees of strength and hardness. The softer coal metals, as they are called, that is, the argillaceous strata cut through at Gilmerton, are so very numerous and various, that it would require a volume to describe them all ; and as a considerable number of them have been described before in the history of coal roofs, it will be needless to give a repetition of them. In short, the strata cut through in this great section contain such an amazing number and variety, that they may be considered as a very complete assemblage and example of the strata which accompany coal, excepting

excepting regularly figured basalt, of which there is none at Gilmerton, though they have cut through several beds of whin of various colours, which approach the quality of that stone.

This vast section and immense variety of strata have not only been cut through in a horizontal direction, by driving level mines through them at various depths below the surface of the earth, but they have also been repeatedly cut through in a perpendicular direction by a very great number of pits, or shafts, of various depths; and although it would be impossible to cut through them all in one particular shaft, yet they have been all frequently cut through by a very great number of different shafts of various depths. Each of these different shafts have cut through a certain number of the strata of this great section in different parts of the field; but if all these shafts which have really cut through different strata were placed one above another in a perpendicular line, it would be a shaft of about nine thousand feet in depth, which happens of course from the greatness of the declivity of the strata; and all the strata in this great section are cut through as effectually and as distinctly by the number of shafts in different places, as if they were cut through by one perpendicular shaft to the whole depth.

The facts here asserted, relating to this great section, are well known to a number of gentlemen

tlemen of knowledge and skill in these matters, so that it is impossible for me to impose upon the public without being detected.

To know with such a degree of certainty what is to be found nine or ten thousand feet below the surface of the ground in any country, is an article in natural history worth attaining. There are but few, if any other, parts of the world which can produce so deep and extensive sections of the strata which compose the superficies of our globe. It is true, indeed, we have traced out much deeper and more extensive sections of the strata in the rivers, glens, and precipices in the Highlands of Scotland, as will be shown and explained in the second volume of this work ; but these sections were cut by the operations of nature ; those at Gilmerton, &c. are the effects of art and industry.

I shall now return to my pursuit of the history of the coal metals. It has been observed, that the general course or bearing of the strata in this island is nearly from north-east to south-west ; but this is so far from being a particular rule that may always be depended on, especially with respect to the coal metals, that we can never presume to know which way they trend, nor which way they dip, until we see some of them. Those strata which decline from the horizon with a considerable degree of slope, are generally

generally found to be more true and constant to the line of bearing, than such as lie much nearer the horizontal position; the reason or cause is obvious. When strata lie very flat, or nearly parallel with the horizon, they frequently vary from the ordinary line of bearing, by waving and wheeling. We sometimes find them waving up and down like a high sea in a calm, after the wind which raised the waves is abated. But this is too brief. We must take more pains to explain this point. It has been laid down as a rule, that the bearing of the strata in general is nearly in a line from north-east to south-west, though this general rule is not without some local exceptions. We shall endeavour to point out and explain the real cause of these exceptions, in order to which, let us suppose, that the coal metals or strata in any field lie pretty flat, or nearly parallel to the horizon; that the strata in that field trend in general towards the south-west; and that the general dip or declivity of the strata in that field is towards the south-east, and the rise towards the north-west, which is in a right line across the bearing. Now, so long as those strata continue to have exactly the same degree of slope, they will also continue to have exactly the same line of bearing; but where the strata are very flat, this perfect regularity seldom stretches a great way in any line, because the
strata

strata which are nearly flat in any particular place, are very often found to fall perfectly flat a little way forward upon the line of bearing, we may suppose at the distance of half a mile; and when they fall quite parallel to the horizon, they very often fall over the horizontal position line, and so acquire for some space a different dip or line of declivity than they had before, and very probably they also trend in a different line from the former for the same space or distance. Let us, for the further explication of this subject, suppose, that the strata are perfectly flat and level with the horizon at any fixed point, as, for instance, in a particular inclosure of so many acres, which is bounded by its own fences, and that when you advance forward out of this inclosure into the next, with your face towards the south-west, the strata then begin by degrees to fall from their level horizontal position, and to dip towards the south-west. In this case the line of declivity is towards the south-west, which was the line of bearing before the strata fell quite flat. Now when, and while the line of declivity is towards the south-west, the bearing of course must be in a line from north-west to south-east, as the line of bearing and the line of declivity always cross each other at right angles. In these cases of the strata flattening, and of their dipping towards another point, it constantly happens that this
change

change of dip is only local, and continues but for a limited space or distance, though the precise distance cannot be determined by us, until we come to know it by observation or experience. But we may suppose that they continue to dip towards the south-west, with an easy slope, for about a quarter of a mile, and when the strata arrive at that point, they generally fall perfectly flat again, and continue so for a limited space, without any sensible dip any way, and at the far side of that space the strata begin to rise gradually towards the south-west, with an easy acclivity, and then the line of declivity is towards the north-east.

At present they rise towards the south-west. A little farther forward in that line the strata arrive at the height of that acclivity, flatten upon the height for a limited space, and still farther forward they gradually begin to dip again towards the south-west, and so on perhaps for many times over again ; and this is what I call the waving of the strata ; and in fact the strata in this case resemble, upon a large scale, the waves of the ocean in a calm day after a storm.

When the strata fall quite flat, or perfectly parallel to the horizon, between these great waves, of consequence they must then spread over a much greater extent of country than before, while they dipped towards the south-east ; and as
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the true line of declivity is supposed to be towards the south-east when the strata fall quite flat, then they must stretch away and spread out far towards the north-west, a great way beyond the former line or limits of the superficies of the strata; and this I call the wheeling of the strata; and in fact, when in this position, they frequently do stretch far beyond the former limits of the superficies or crop of the strata, and fetch a great compass over an extent of country, sometimes of miles north-west of the former crop or outburst. When the horizontal strata, from dipping a little towards the south-east, fall quite flat, they sometimes do not stop there, but fall over, that is, the north-west side of that class or range of strata fall quite over the horizontal level, and dip for some distance towards the north-west, which occasions the strata to stretch still farther towards that point, than if they only fell quite flat or parallel to the horizon. The truth is, when once the strata come to a horizontal flatness, they are often found, while they continue near that position, to lean and dip this way and that, without the least regard to the true line of bearing or declivity.

While the strata continue in this horizontal position, they are sometimes found equally flat, that is, to continue upon a level plane for a considerable extent of ground; but more frequently they

they are only found to be flat in general with respect to their spreading over an extensive country ; but with respect to different particular spots or compartments of that country, they are found to lean this way and that at much uncertainty ; sometimes forming ridges and troughs, and sometimes a bason ; and these various changes of dip and rise in the horizontal coal metals, are sometimes upon a large scale, and sometimes upon a small one. What I mean by a bason in the horizontal strata is, when any extent of them of less or greater dimensions fall lowest in the middle, and rise gradually towards the outskirts, all round, in the form of a piece of low hollow ground in a meadow, which contains a lake of stagnant water in a rainy season ; and to form this bason in flat seams of coal, it must be understood that the strata dip inward all round towards a common center, and of course there must be an acclivity or rise of the strata from that center quite round towards the outskirts of that bason. It cannot be supposed that these basons dip regularly towards the center in a perfect circular form ; however, I have seen some of them so near it, that the eye could not determine at once, without examining circumstances, which was the shortest or which the longest diameter of the circle. These basons, as well as all the other various positions of the strata, are found upon va-

rious scales. Some of them are not a quarter of a mile in diameter before the seam of coal and other strata stretch away in a different position, and some of them are much more than a mile in diameter ; and it generally happens, that in these large basons the dip and rise of the coal are so little and gradual as hardly to be perceived in some parts.

When these various local declinations of the flat-lying strata happen to be upon a large scale, it makes smooth work in carrying on a colliery in any of them, because you advance a great way before you come to any sensible change of the dip and rise that will any way affect and disturb the plan of working ; but on the contrary, when the waving and wheeling of the strata is upon a small scale, the different sudden changes of the dip and rise are frequently very troublesome and expensive. As, for instance, the narrower or smaller a trough is, it generally happens that the coal and other strata dip down the more precipitately, in proportion to the small dimensions of the trough, and of consequence it is more difficult to work down a sudden precipitate slope than a gradual easy slope, and especially if there is much water in the mine. The same difficulty occurs when we meet with high and narrow ridges between troughs. We may ascend up the nearest side of one of these

these ridges, and work away over the top or highest part of it very well ; but when we begin to descend down the far side of it, we immediately find water, and perhaps cannot proceed until we go back to the lowest place, and bring up a level mine under the pavement of the coal, quite through the ridge, in order to level the coal upon the other side of it. Some of the Scots colliers call this a *ridge*, others of them call it a *hirst*, and some of them call it a *sow's-back* ; but all the hollow parts in the coal are called troughs by them, whether they are troughs or basons, &c. The coal is sometimes found thinner than ordinary upon the top of a sow's-back or a narrow ridge, but when the waving of the strata is so gradual as to make the dip and rise of the coal scarcely perceptible, the thickness of the coal is but seldom affected, either by the ridges or the troughs.

I observed above, that these ridges and troughs sometimes resemble long and large waves of the sea ; but it may be proper for me farther to observe, that these ridges are in some places upon so large a scale, that the waves of water are not suited to convey an adequate idea of the spacious dimensions of the troughs, and of the ample extent and magnitude of the ridges. Every body must have seen long and low mountains or ridges of rising ground running parallel to one another,
with

with valleys of moderate extent or breadth interposed between them. In some places, the waving of the strata is upon so large a scale as to resemble these parallel ridges and valleys which diversify the face of the country.

Let it not be imagined that all this bustle about the waving and wheeling, and other various declinations of the coal metals, is the work of fancy, an imaginary scheme to amuse such as are ignorant of these matters. It is a fact well known to all who are acquainted with the natural history of the strata, and the fact is obvious to the observation of such as look into these matters, and it might be proved by a number of local instances. The horizontal coals which are worked in Mid-Lothian in Scotland, all round Dalkeith, are found to wave considerably in several places, particularly when they go south towards the parishes of Carington and Temple, and farther west, in the parish of Linton in Tweeddale; some of those coals have been worked in the lands of Carlops, through several troughs and over several ridges.

The coal which has been mostly worked out in the farm of Carlops, so far as they could reach it with adits or levels, is all of it found in the waving order, that is, in ridges and troughs, and the variation of the dip and rise there generally consists of gentle easy swelling waves, and I know that the coal is whole and unwrought in the bot-

tom

tom of some of the troughs there, because they could not drain it with their levels; and, moreover, it is known to several coal-masters, that the splenty coal and others, which are wrought to the south-west of Dalkeith, across under the rivers North and South Esk, ascend the north side of the hill or rising ground to the south of Dalkeith,—cross the height of that hill by Blackside, &c. and then descend quite down the south side of the hill, and cross the valley by Oxenford and Cranston, and are actually seen and wrought upon the south side of the valley and river at Cranston, so that here they are found to wave, or to rise and fall, upon a large scale, as the extent of the ground now mentioned is about five miles in a line from Lasswade, which is situated a little westward of Dalkeith, to the farthest place where these coals have been worked upon the south side of the river at Cranston; and in this line the splent coal, &c. has been worked, and is now working by John Clerk, Esq; of Eldin,—by the Marquis of Lothian in several places south of Dalkeith,—by Sir John Dalrymple at Blackside, and also upon both sides of the river at Cranston. I could produce a great many more instances in point, but these are sufficient to shew the fact, and to confirm the doctrine of the waving of the strata.

From

From this investigation of the subject, that is, from the result of these enquiries about the waving and wheeling of the horizontal strata of coal, it is obvious at first glance that this variation of the strata from the common lines of bearing and declivity, is so far from deserving to be reckoned in general among the ordinary troubles and irregularities of the strata, that in fact, instead of being a nuisance, they are in general a great benefit to society. Their falling very flat, and sometimes falling quite over the horizontal level, and dipping the contrary way, and their waving up and down, as described, spreads abroad the same individual stratum, or a number of strata of coal, over a much greater extent of country than if they preserved invariably the same degree of declivity, and the same line of bearing, as they are found to have before they fell quite parallel to the horizon. Their falling sometimes quite flat, and their declining this way and that, in the variety of positions described, keeps the coals floating near the surface, within our reach, over an extensive country, by which means we can, at a moderate expence, work ten times more of them; in some instances, perhaps, we can work twenty times more of them than if they dipped down towards the center with an uniform and invariable slope or declivity; for if the line of declivity was
invariable,

invariable, however easy and gradual the slope might be, they would too soon dip down quite out of our reach. But matters are much better disposed for our good, as by means of the parallel slips described above, which throw the same coals many times up again nearer the surface, which gives us the same seams of coal many times over again; and, by means of this waving and floating of the coals near the surface, we have a much greater fund of them in our power than we could have by any uniformity of the strata. There is an instance of this at Pitfirran in Fife, where the coals dip towards various points of the compass, and in consequence, I believe, that they have already worked out ten times more coals there, than they could have done with one uniform line of bearing and declivity.

Here we have an opportunity of admiring the wisdom and benevolent designs of providence, in making the irregularities of the strata, which may be thought by some to be the blemishes of nature, yet these are made to turn out for the convenience and emolument of society. But I mean to show in another place, that the breaks and irregularities of the strata are not blemishes of nature, but that they are all of them the necessary and unavoidable result and effects of natural and necessary causes.

Before

Before I leave this topick, I should observe, that although the coals and coal metals are found sometimes to fall from different degrees of declivity to a horizontal flatness, and while they continue near that position, that they wave and wheel, and vary the slope and bearing, and so float and spread near the surface over an extent of country, yet it must not be understood that they always continue in this waving position. In some coal fields they do continue in the horizontal waving position over an extent of country of several miles every way, but in other places they do not spread so wide before they fall back towards the first and regular line of bearing, and again acquire a regular stretch, bearing, and declivity; and when the strata are thus reduced to a more uniform bearing and declivity, there is no such thing as determining the degree of slope they may fall to. I have seen some coals acquire a horizontal and a waving position, and afterwards, farther towards the south-west or towards the north-east, I have seen the declivity again fall so steep as the angle forty-five, and in some particular instances I have seen them still nigher the vertical position. There are also some instances of their not recovering the former regular bearing and declivity, but continue to wave and wheel to the extremity of the limits of the coal field, especially towards the south-west. We have

have an instance of this in the horizontal coal metals of Mid-Lothian, which never recover a regular, uniform, and continued line of bearing and declivity; after they once begin to wave, until they arrive at the extreme boundary of the coal metals towards the south-west, and I could produce other instances if necessary.

There is yet another circumstance relating to the strata of coal, which I should note in this place. I have made it evidently appear, that the strata of coal, and their concomitants, sometimes vary from the true line of bearing considerably, by falling to the horizontal position, and by waving and wheeling, &c.; but in this case, however, the true line of bearing ceases to be the dead level line, as any change in the degree, or in the line of declivity, changes the dead level line; yet it generally happens, nevertheless, that there really is coal still in the true line of bearing all the way to the extreme boundary of the coal field, although that line ceases to be the dead level line, and, therefore, we cannot determine, without experience, at what depth it is to be found. We reckon the true line of bearing, or what may be called the bearing of the strata, in general through the Island of Britain, to be nearly from north-east to south-west. When this line is lost in any particular place in a coal field by the flattening and

waving of the strata, it enlarges the coal field in breadth, but it does not follow that the coals are lost in any part of the line.

I believe that there are many who imagine that the coals below resemble the figure of the surface of the ground above, and that they are affected by it; and I apprehend that my observations about the various changes of declivity in horizontal strata, and the instances adduced in proof of that variety, may be construed by some as a confirmation of that opinion. If the notion were true, that the disposition of the strata below ground resembles the figure of the surface above, I apprehend that the observation might be so improved as to be of great utility in practice. Upon this supposition, when we see an uniformly regular surface, we might expect that the subterranean geography would also be regular. When we see a wavy country, which gently swells into broad ridges, and sinks into hollow valleys, we might then expect that the strata would likewise wave up and down; and when we meet with a rugged broken surface, we should be led to expect as much irregularity below ground as above.

This hypothesis may appear to some at first sight at least plausible, and there may be instances found where the dip and rise of the strata appear to confirm the hypothesis; but these instances are so few, and there is so much of chance in them, that

that whoever shall depend upon always finding this correspondence, will be frequently disappointed, because such an instance is a mere chance, and, therefore, in such cases we shall always find it wisest and best to suspend our judgment until we can bring observation and experience in aid. These will infallibly lead us the nearest way to the truth. Opinion and ill-grounded notions will generally lead us astray.

I have frequently seen great irregularity and disorder beneath a regular unbroken level surface; and, on the contrary, I have seen the strata remarkably plain and regular underneath a rugged unequal broken surface. In some few places, we see the strata for a little way dip and rise as the surface of the ground does; but this in general is all chance, and of short continuance. It is no rule upon which we can depend, for we shall as often, and much oftener, find them dipping into the hill, against the rise of the surface of the ground, and across it in a right and in a diagonal direction, and to all points, without regard to the figure or quality of the surface.

I have in some places seen low hills in coal countries which swelled to a round or oval figure, with an easy rise or ascent upon all sides, in which the strata appeared to dip and rise almost all round, nearly with the same slope as the surface of the ground; and, on the contrary, in other
little

little hills of the same figure, I have seen the strata dipping into the hill upon all sides, so that each stratum on such little hill formed the figure of a basin, and all the strata in the hill formed a nest or pile of basins within one another; but these are uncommon instances, seldom to be met with, and only to be seen in a very few places, where circumstances favour the discovery, and which are never to be regarded as a rule.

The declivity of the coal metals is so variable, both in respect to the degree of slope, and to the point towards which they dip, that we have no sure rule which will guide us every where to judge of it but observation and experience, for we find them as often dipping against the slope of the ground as with it. Sometimes we find the strata in a coal country running parallel to the side of a hill, or ridge of ground, and we as often find them crossing such a hill in a right and in a diagonal line.

The coals, lime-stones, and other strata run almost right across the Bathgate hills in West-Lothian, and almost right across the high and low grounds contiguous to those hills upon both sides; and although the coals and other strata climb quite over the high ground to the south of Dalkeith, and across the low grounds at Cranston, as I pointed out above, yet this has
more

more relation to the waving of the strata than to the waving of the surface of the ground.

As a proof of this assertion, the strata, as I already hinted, run nearly right across the Bathgate hills, and of the valleys and high grounds upon both sides, from the south side of the Forth until they cross the river Breich, south-west of Mid-Calder; yet it is to be observed, that the strata of coal, lime-stone, and others in those high and low grounds, decline sometimes towards the west, and sometimes towards the east, which must be owing to the waving of the strata, but then they do not wave with the surface of the ground. The ridges and valleys here run nearly east and west, but the bearing of the strata is nearly north and south; and whether the strata dip to the west or to the east, the same line of bearing towards the south is still continued, and of consequence the difference of dip or declivity of the strata must be occasioned by their waving up and down, without any regard to the figure of the strata.

In all my observations, which have been pretty extensive, I never yet found that the external figure of the surface governed the position or the bearing and declivity of the strata below, and, therefore, I infer, that wherever the coal and other strata below are found to dip and rise as the surface of the ground does above, it is merely accidental and by chance, without the least relation

tion or respect to any rule or regular law of nature. And even in the instance above-mentioned to the south of Dalkeith, where the strata pass under the valleys, and climb over the high grounds, yet even there they are far from dipping and rising every where with the surface of the ground; on the contrary, the rise and declivity of the strata are found to be different from the slope of the surface in several places within the distance above-mentioned, which must be owing to the waving of the strata, and to the various degrees of declivity in different places.

I have dwelt the longer upon this part of my subject, and have taken pains thoroughly to search it out, with a view to obviate the mistaken notion which many entertain of the coal strata preserving one continued line of bearing invariably, and to set people on their guard against the consequences of such a mistaken notion.

From all the observations which I have made in the course of my solitary perambulations, and from my long experience, I may safely draw this general conclusion, and lay it down as a rule, namely, that we can place no dependance upon the bearing and declivity of the strata, at any considerable distance out of our sight and knowledge of them, and more especially the horizontal strata, because they are so often thrown out of the course of both, by waving and wheeling, and by dykes, slips,

slips, &c. which ought to make people more cautious than they often are in launching out expences in sinking for coal at hazard, from a confident persuasion of its running invariably upon one line of bearing through the whole length of a country. Experience will often in this case punish them for their temerity when they find that they are wrong.

I have frequently seen, in a great number of places, the horizontal strata varying the line of bearing by their falling flat, and then dipping towards various points different from the former line of declivity, and by these means spreading abroad over a great extent of country, quite out of the former line of bearing, which I have proved to be a great benefit to the community in general, as by this means the coals are kept floating near enough to the surface to be worked, sometimes for several miles every way; from which I infer, that if they are thus liable to be diverted out of the former line of bearing, we ought not to risk too much upon an uncertainty. There are more chances of the coals being turned off the line of bearing than of their continuing in it at any considerable distance; and as there are means of ascertaining the point, we should be well assured of coal before we launch into expensive trials for it.

With

With respect to such strata of coal as have a great degree of slope, it may be observed of them in general, that they are more regular in the lines of bearing and declivity than the horizontal strata. When the line of declivity of a seam of coal, with its concomitant strata, approach the angle forty-five, or a few degrees above or below that angle, the strata are found to be much more regular in their declivity and bearing than when they are very flat; however, even these are not so regular as not to vary, and sometimes considerably.

In some coal countries we find classes or arrangements of coal seams, with their concomitant strata, dipping down with so much precipitation as to be denominated edge-seams; and sometimes, in the same neighbourhood, we shall have another class of coals, &c. lying very flat, and both of these running parallel to one another. We have an instance of this in the edge-coal seams of Gilmer-ton, &c. near Edinburgh, and of the flat coals to the south of them.

The edge seams, as I observed before, are in general much more regular in the bearing and declivity of the strata than such as are very flat, notwithstanding we find neither of them so regular as not to meet with great variations. In tracing the course of edge-seams backward and forward upon the line of bearing, I have frequently seen them vary considerably in the degree of declivity

clivity, so as in some places to become nearly and even altogether as flat as some of the horizontal coals, which in Scotland are denominated flat-broad coals; and, in other places, I have seen them turned up quite on edge, or into a vertical position. There is an instance of both these variations to be seen in the edge-coals and coal metals to the south of Edinburgh. This arrangement of coals, with their concomitant strata, trend away from the south side of the Forth by Duddingstone, Niddry, Edmondstone, Gilmerton, Loanhead, and other places. There are more than sixty seams of these edge-coals, thick and thin, and in some places in their course there are more than twenty seams of them workable.

This class of coal-seams, with their concomitant strata, dip towards the south-east, and rise towards the north-west, and of consequence the bearing or dead level line, which is the same as the line of bearing, is towards the south-west. I am pretty well acquainted with these coals and their concomitant strata, from the sea at Duddingstone, for about sixteen miles south-west upon the line of bearing, where they terminate and go no farther in that line, but turn away in a right angle towards the south-east. I have seen these coals in many places upon this line of bearing, which is about sixteen miles long, and in general they are very regular in the lines of declivity and

bearing. These coals are called edge-seams, because they dip precipitately with a very great slope. The general degree of the declivity of these coals is about the angle forty-five from the horizon. In some places they stand higher, that is, more upright, and in other places some lower; but I think that the medium dip is about forty-five, or at most forty-seven degrees.

There are but few places in Scotland where a class of coals and coal metals can be traced so far as these in a straight line, which naturally infers, that these coals stretch away up the country very regularly in the true line of bearing, and consequently that the declivity of these coals is likewise very regular, as in fact the mutual regularity of these two lines, when applied to seams of coal, depend upon one another. But notwithstanding the remarkable regularity of the bearing and declivity of these coals in general for so long a stretch, there are by the way in some places considerable deviations from both. At a place called the Bank, betwixt Edmonstone and Niddry, about two miles south-west from the sea these strata are found perfectly in a vertical position. In proof of this, coal-pits of considerable depth have been sunk in a seam of coal from top to bottom without going out of the coal the whole depth, either into the roof, which is upon one side, nor into the pavement, which is upon the other side
of

of the seam of coal ; and this is the clearest proof imaginable of their being in a vertical position, as these pits are sunk by a plumb line perfectly perpendicular.

I hinted before, that the superficies of a considerable number of these strata are cut in the side of the high road from Edinburgh to Dalkeith, near Edmondstone, where they likewise appear to stand in a vertical position ; and this place is about half a mile south-west from the Bank. At Gilmerton, which is more than a mile south-west of the Bank, the greatest number of the edge-seams decline much about the angle forty-five, though some of the southmost of the coals are higher, but then some of the northmost of them are lower, and therefore I reckon the angle forty-five to be the medium dip in that ground.—Some of these coals are pretty near to one another, and others of them are farther asunder ; but the northmost of all the seams which have been worked is much farther off than any of the rest, that is, there is a much greater distance betwixt this seam and the next workable coal to the south of it, than there is betwixt any other two seams in the whole field ; and, as they still flatten by degrees, the farther north we advance, this coal, which is called the North-green seam, is considerably flatter than the rest, especially towards the north-east end of the coal field, which

is about a mile long upon the bearing of the coal. In the south-west end of this field, the North-green seam stands as much on edge as the rest of the coals. About the middle of the field it is somewhat flatter than any of them, and in the north-east end it is considerably flatter, and, of consequence, the seam stretches farther out towards the north-west. In one place near the north-east end of that field, this coal first falls quite flat, and afterwards falls quite over, so as to dip towards the north-west, which is diametrically opposite to the real true dip or line of declivity, which is towards the south-east; and the North-green seam continues in this north-west declivity a considerable way over the ordinary line of the crop of this coal.

This tongue of the North-green seam is about half a mile broad, but it stretches away towards the north-west more than half a mile over the ordinary line of bearing. The coal and other strata in this place fall over in a kind of trough, so that the middle of the tongue is by far the deepest part of it; and it rises and crops out upon both sides, that is, towards the south-west and towards the north-east, so that there is a dip or declivity from both these sides towards the middle of the trough, and the middle of the trough dips away towards the north-west.

Perhaps

Perhaps I may not be perfectly understood in pointing out these different dips; but as Gilmerton is near Edinburgh, young gentlemen can go out and investigate circumstances upon the spot, which is very practicable, as a fine lime-quarry lies below this coal, and the quarry is wrought upon both sides of the tongue; and as the quarry dips and rises just as the coal does, the various declivities mentioned will be easily traced out.

Gilmerton lime-quarry is worked under ground by leaving pillars to support the incumbent weight of the rock above; these subterranean lime-works are singular and extensive, and their magnificent appearance strikes the imagination with a pleasing awe and astonishment.

Slips in edge-seams throw them more to one side than up and down. There is a large slip about the middle of the coal-field at Gilmerton, which throws the coal upon the west side of the slip, about one hundred and sixty yards farther south than they are upon the east side of it. At first sight, this may appear as a deviation from the true line of bearing, but I reckon very little upon such a slip, because another slip may throw the coals as far to the north as this has thrown them to the south.

These variations in the lines of the bearing and declivity of the edge-seams are sufficient to shew, that there is perhaps no such thing as a long stretch

stretch of the strata of coal any way in a straight line, without some deviations in the lines of declivity and bearing, and yet these run in as straight a line as any that can be pointed out in the country; and, moreover, what I observed above, will generally hold true in all coals, viz. that the greater the slope or declivity of the coals and coal metals, the truer and more regular they will be found, both in the line of declivity and in the line of bearing; but, in general, so much the worse for the community, because the coals dip down so suddenly out of our reach, that we can work but a small quantity of them in comparison of the flat broad coals, and especially in comparison of such flat coals as in some places wave and wheel over a great extent of country.

There are yet other deviations from the true line of the bearing of edge metals, and such as have a considerable degree of slope, besides the two instances now mentioned. I have frequently seen them bend like an elbow, and then run in another direction from the former line of bearing. As thus, supposing the line of bearing to be south-west as you advance along this line, you come to a place where the strata bend backward and turn away to the west, and sometimes towards the north-west. But the strata in these deviations do not always bend backwards. They sometimes turn the contrary way, and from a south-west

south-west direction come to point towards the south, and even towards the south-east. These bendings in the line of bearing of the edge coals are exceedingly various. Sometimes they only bend a little either towards the west or towards the south, with an angle so obtuse, that it is scarcely discernible at first sight, and sometimes they take a quicker and more sensible turn ; and again, they are not all alike in respect to the manner of turning. In some of them the strata come about with a gentle, easy bend or sweep, and in others they turn shorter, either with an obtuse or a right angle, and after these turns, the strata bear away towards the new point which they have gained by the turn sometimes to a considerable distance ; but it is not common for them to stretch very far upon this new tack before they turn again and come into their former line. When these traverses in the line of the bearing of the strata are short, that is, when there is but a short distance between the several angles or turnings, it would be exceeding difficult to work a seam of coal in such ground.

I have seen upon the sea-shores, and in other places where the strata were laid bare, some of these traverses or angles so near to one another, that it would be impracticable to work coal in them, the strata in that case being too much distorted and broken by being so often turned and
twisted

twisted to and fro ; but when there is a considerable distance between each turn or angle, the strata are generally as perfect between the turns as in any other place, and in that case coals may be wrought very well. The edge-seams of Gilmer-ton and Loanhead, &c. have some of these bendings in the line of bearing, and that both backward and forward, that is, in some places they bend a little backward, or towards the west, and in other places they bend a little forward, so as to point more towards the south than before ; but there is no turn in these strata between Dudding-stone and Carlops so considerable as to come any thing near a right angle.

A great deal may be said hereafter for the information of the public about the inferior and the superior, or the nether and upper strata of coal.

It may perhaps in time be found, that the inferior coals have a greater degree of slope, and are more regular in the line of bearing than the superior coals ; and, on the contrary, that the superior strata of coals are generally more flat and horizontal than the inferior ; and that they more frequently wave up and down, and float near the surface over the face of the coal countries.

But as this part of the natural history of the strata of coal leads into abstruse disquisitions, and as the thought is but new to me, having had as yet

yet neither time nor opportunities of investigating circumstances with a view to ascertain the fact, I must at present drop the point, and leave it to be examined by others.

All that I can say to it just now is, that there are classes or arrangements of edge coals, with their concomitant strata, at Gilmerton, &c. to the south of Edinburgh, and there are a number of flat seams of coal, with their concomitant strata, lying to the south of the edge-seams, and running parallel to them all the way from the seashore near Musselburgh, as far up the country as the edge-seams stretch in the line of bearing, which is, as I hinted before, about sixteen miles.

I have in several places seen the point of contact, or rather the line of contact, where the south side of the edge metals join to the north side of the flat metals or strata; and, in other places, where I have seen them join, both the edge and the flat strata appear in full perfection; that is, they are both of them firm and good, without any confusion or disorder, and the flat metals are immediately flat, and the edge metals are immediately on edge, where they come in contact with one another. It is generally supposed by those who understand these matters in the Lothians, that the edge-seams do stretch way under the flat coals, and also under the valley at Dalkeith, and that they rise up again about five or six

miles to the south-east of Gilmerton, &c. where they begin to dip down precipitately towards the south-east.

It must be confessed that this hypothesis is very plausible, but to me it is very doubtful, and, therefore, I will leave it as a doubt, although I have very good reasons to suspect that the edge seams do not rise again from under the flat coal towards the south-east. I have been hitherto very careful not to admit or introduce any thing into the natural history of the coal, but what I was certain of being truth from my own observation and experience, and I am resolved to keep strictly by the same rule for the future.—Whatever faults, whatever imperfections may be found in these papers, and perhaps there will be plenty of both, yet I am resolved that there shall be none in point of truth. I will not introduce hypothetical conjectures as matters of fact.

The next question relating to the history of coal, which falls naturally to be examined, is the extent of coal fields or coal countries.

Many are of opinion that the strata of coal keep their course in general in the line of bearing quite through the island, and perhaps round the globe.

I have heard coal-masters of great knowledge, and who were, moreover, men of sound judgment,

ment, assert, that the coals and coal metals stretch away in under the mountains, and emerge again upon the other side, and keep their course, or trend in general to a certain point; and this was once my own opinion,—but it was my opinion when I had not so much knowledge and experience as I have now acquired; for I am now fully persuaded of the contrary, and my persuasion is founded upon the clearest conviction—from a full demonstration of the truth; and this conviction I obtained by many observations—by frequently examining the same class of circumstances in many and in distant places, all of which agree and amount to a full proof in point.

In refutation of an opinion so generally received, I reckon that nothing short of a clear demonstration of matter of fact is sufficient, as one man's opinion is as good as another's; and therefore, in order to decide this point, I will recapitulate and examine some of those circumstances.

I observed above, that I was formerly of opinion that the coals, and their concomitant strata, did push their way under the mountains, and emerged again upon the other side. But as I have been long and much in the practice of viewing and examining all circumstances in my power, relating to the strata which form the superficies of our globe, I was resolved thoroughly to investigate this point. In order to which, I
carefully

carefully examined several places in distant parts of the country where the coal metals end, and those of the mountain rocks begin, in expectation of seeing the coals and coal metals thrown down, and the other classes of different strata riding above them; but I never could observe any symptoms of this being the case in any one place I examined; on the contrary, I every where saw the clearest demonstration of the coal and coal metals being upmost, and of the other different strata pushing in below them. I have in several places seen the coal metals, where they approached the side of a hill, or any other place where different foreign strata commenced, discover great irregularity; and when they came in contact with the foreign strata, the coals and coal metals were evidently thrown up, and in the highest degree of confusion and imperfection imaginable, so that the coal appeared to be no better than dross or foot, and the hardest stones among the concomitant strata no better than rubbish or sand; whereas, on the contrary, the new or foreign class of strata emerged from under this confused imperfect mass in full perfection of quality and regularity of strata. In some places where the seams of coal and their concomitant strata approached the outskirts or extremity of the coal country, I have seen the coal seams first begin to grow thin and troubled, even at a considerable distance,

and

and then, as they advanced nearer the extremity, grow more and more troubled and distorted, and at last, when they arrived at the extremity, the coal seams of several feet thick were squeezed and dwindled away to hardly as many inches, and the coals, with their concomitant strata, forced round, quite out of their natural course, so as to cross the true line of bearing at right angles, but in the highest confusion imaginable, and entirely useless; whereas, on the contrary, those different strata, which commenced instead of the coal metals, were perfectly regular and good, and trending away in the true line of bearing to the point the coal metals trended to before they were thrown out of the ground, and lost their course.

Now, it is impossible to have a clearer proof of the extremity of the outbounds of a coal field than what I have pointed out. I have seen this change commence in low situations, at several miles distance from any mountains or hills, in the true and real line of bearing, both of the coal metals and of other different strata; and I have seen still lower ground farther forward in the same line, after the new strata commenced, than where the change took place; and in this lower ground the new range of strata appeared in a great many places, keeping the same regular course or line of bearing which the coals and coal metals had lost.

As

As local examples are most convincing and demonstrative in such disquisitions as these, I will give an eminent instance of this not far from Edinburgh, which may be examined by mineral students, and when they have thoroughly investigated it, they will find it a clear and satisfactory proof of what I have advanced upon this point.

I have already mentioned and described the edge coals to the south of Edinburgh, and shewed, that the north-east end of this class of coals, with their concomitant strata, appear first in our sight upon the sea-shore at Easter Duddingstone, and that they trend away from thence towards the south-west by Gilmerton and other places for about sixteen miles, and there is not perhaps one quarter of a mile of the whole sixteen where these coals have not either been wrought, or else are to be seen crossing the rivulets which run down from the Pentland hills right across the superficies of these strata.

Many of these seams of coal are either now working or have been wrought at Duddingstone, Niddry, the Bank, Edmondstone, Drum, Gilmerton, Melvill-Moor, Loanhead, Dryden, Greenlaw, Cooking-Parks, Pennycuik, and Newhall. All these places are set down in the order of their situation as we advance from Duddingstone towards the south-west; and Newhall, which is the
last

last mentioned, is at least sixteen miles from Duddingstone. The lands of Newhall are about two miles long upon the line of bearing, that is, from north-east to south-west. The edge coals are seen in perfection about the middle of those lands, only, that the greatest number of the seams are thinner here than farther east; and at the place or mansion-house of Newhall, which is a little farther south-west than the middle of the ground, some of the edge seams have been wrought, but they were found there much troubled and in considerable disorder; and less than half a mile farther south-west than the place or mansion-house of Newhall, these coals arrive at the utmost boundary or extremity of the coal field in the line of bearing. The bridge of Carlops over the North Esk, is about half a mile westward from the house of Newhall. About a hundred yards, or a little more below this bridge, the river begins to run across the superficies of these coals and their concomitants in a diagonal direction. The lands of Newhall are upon the north, and the lands of Carlops upon the south side of the river where it runs across the coals.—The banks of the river in that place are very high, and the strata of coals and coal metals are seen distinctly from both sides, and likewise in the bed of the river. The north bank of the river
upon

upon the Newhall side is much higher than the south or Carlops side ; and in this north side we see many of the seams of coal and their concomitant strata, but we see them in such disorder and confusion as is not easy to be described.

In some parts of that north bank of the river, the strongest post-stone and the soft coal metals are twisted and blended together into a perfect chaos, and in other parts of the bank where something like strata is to be seen, both the coals and their concomitant strata have been so squeezed, twisted, and degenerated as to be rendered entirely useless. About eight or ten miles farther north-east, some of these seams of coal are up to six, seven, or eight feet thick, and one of them, called the great seam, is in some places about fourteen feet thick ; but where these capital seams of fine coal cross the Esk betwixt Newhall and Carlops, there is not any of them regularly up to one foot thick ; the most of them are only four or five inches, and some of them much less : all these coal seams, with their concomitant strata, are squeezed and distorted into the greatest confusion and disorder, and they are squeezed together into much less room in the line across the strata, and, moreover, they are turned from the south-west to a southerly direction. About a quarter of a mile farther forward, towards the south, they complete

plete the turn to a right angle, that is, the course is changed from a south-west to a south-east line of bearing.

The river Esk issues out from among the Pentland hills, immediately at the bridge of Carlops; and it is remarkable, that the rocky base of the south side of those hills comes down close to the river side, immediately below the bridge, and continues close to it for about three hundred yards farther down; and in that very place the south-west line of the edge metals, which is the true line of bearing, glances in a slanting direction against the side of the base of the hills.

Now, if the coals really immersed and passed away under the mountains, we should certainly lose sight of the edge seams in this place; but the fact is, that we do not lose sight of them: On the contrary, we evidently see them rising up and cropping out, instead of being immersed under the hills; and, moreover, we evidently see that the outbursts or crops of them are squeezed and distorted, and thrown into endless confusion, where they come in contact with the base of the hills; and we also see the crops of them turn away towards the south and south-east, in a right angle to the former line of bearing; and all this is as evident as ocular demonstration can make it.

I have already observed, that there are horizontal coals, with their concomitant strata, imme-

diately upon the south side of the edge coals ; and that these flat coals run parallel to the edge coals all the way from the shore of the Forth, as far to the south-west as this class of strata are found to stretch. Some of these flat coals are found in the lands of Carlops in their proper situation, parallel to the edge coals ; however, they go no farther in the line of bearing ; but these, as well as the edge coals, are also found to crop out towards the south-west, or former line of bearing, and the crops of them likewise turn away gradually to the southward, with a gentle sweep round, until they at last gain a south-east direction ; but it is observable, that these flat coals are not thrown into such confusion and disorder at the turn and extremity of the field as the edge coals, because they are at some distance from the root of the Pentland hills, which comes in contact with the edge metals, and disturbs and throws them up, and out of their true course, a little before they arrive at the extreme boundary of the coal field.

Now, the fact of the flat metals turning from a south-west to a south-east direction, is evident to ocular demonstration two different ways.

First, the crops of the flat coals, and of the lime-stones which accompany them, are seen and wrought in several places upon the turn, and after they have gained a south-east direction ;—and, secondly,

secondly, Other rocks of quite a different quality are seen in a great number of places in lower ground in the former or south-west line of bearing, viz. in the river Line, and several other places round the village of Linton, and in a great number of places, over a large extent of country to the south and west of Linton.

I have traced the crops or outward extremity of these coals, and their concomitant strata, more than fifteen miles from Carlops, upon the south-east bearing, and see evidently that they do not immerge under cover, and stretch away again any where towards the south; on the contrary, they are seen to crop out in the farm of Carlops, and likewise in the lands of Magbiehill, to the south of Carlops. They are also seen to crop out upon the south side of the Wheem, which is still farther east; and, afterwards, they crop out over a great extent of pretty high moory ground, betwixt the Wheem and the foot of the Moorfoot hills, to the south of Arncliffe, where I do not know the names of particular places.

Now, in all this extent of country, strata and rocks, of a quite different quality from the coal metals, are every where seen immediately upon the outside of the crops, or outburst of the coal metals; and, moreover, as a farther proof that they do not any where stretch away towards the south-west, the river Line runs
nearly

nearly parallel to them, and in much lower ground; and this river washes the superficies of the strata all the way from the Pentland hills, down until it falls into the Tweed, and afterwards the Tweed washes them clean to Peebles; and in all that distance, which is near twenty miles, nothing but strata of the mountain rocks appear, which are entirely of a different quality from the coal metals; and all the rivulets and broken places of the surface, all along upon the south and west side of the extremity of the coals, discover the same sort of strata as are seen in the rivers Line and Tweed. Thus far I have seen the trending and outburst of the coal strata; and thus far I can answer for the truth of my observations.

To the south and south-west of Arncliffe, the flat coal metals approach the north-west side of the Lammer or Moorfoot hills, and there they turn first to an easterly, and then, by degrees, to a north-east direction; and they afterwards continue to crop out to the south-east, and to trend towards the north-east, until they immerge into the Forth, to the west of North Berwick. There are a few miles of this course from the skirts of the Moorfoot hills, south of Arncliffe, to Blackshiels, which I have not seen; but from many circumstances too tedious to be explained, I am confident that the flat coals crop out to the south-east

east in that short extent, as well as all the rest of the extremity of this coal field; all round the most of which, I have not only seen, but have minutely examined all circumstances in it relating to the extent, bearing, and declivity of the strata of coals and coal metals.

From what I have advanced upon this head, I think myself fully authorized to make the two following inferences or conclusions, which are naturally suggested as the result of these researches and observations, viz. First, it evidently appears, even to ocular demonstration, that the coals and coal metals do not immerge under the high mountains, stretch away through beneath them, and rise again upon the other side of them;—and, secondly, it also appears evident to ocular demonstration, that coal fields or coal countries are but patches of limited, though different dimensions; so that the extent every way of the coals, and their concomitant strata, wherever found, may very aptly be called the coal field, as different fields of corn or grass are of different dimensions, but still they all have their limits.

The Mid-Lothian coal field is nearly a square of about fifteen miles over every way, though it is not an exact square. The frith of Forth is the boundary of the north end of this square. The west side of it trends away from the shore of the Forth near Duddingstone, towards the south-west,

west, in a line almost parallel with the Pentland hills ; but this line, by slow degrees, approaches nearer to the south-east side of those hills as it advances westward, until at last it comes in contact with the base of the hill at the bridge of Carlops ; and this line, from the sea-shore to the bridge of Carlops, is about sixteen miles long, and there that line and that side of the coal field ends.

From Carlops, the coals and the coal metals trend away in a south-east direction to the skirts of the Moorfoot hills, pretty nearly, though perhaps not exactly in a straight line ; and I suppose that the distance betwixt Carlops and the Moorfoot hills in that line, will be about fifteen or sixteen miles.

From the point where the coal metals approach those hills, they trend away in a north-east direction, parallel to the line from Duddingstone to Carlops ; and this north-east line continues until the coals and coal metals immerge into the Forth, a few miles west of North Berwick. I do not exactly know the length of this south-east side of the coal field, but I evidently see that it is somewhat longer than the north-west side, which runs parallel to it.

The public road to England from Edinburgh by Dalkeith and Blackshiels, runs almost in a right angle across this coal field. I think it is fifteen

teen miles from Edinburgh to Blackshiels. The coal field commences upon that road about two miles south of Edinburgh, and it ends near Blackshiels. Coals have been wrought near that place upon the north side, and I have evidently seen the mountain rocks a little way south of Blackshiels; and, therefore, the southern extremity is thereabouts, so that the line across the coal field upon this road is about thirteen miles long. The line across it, upon the road from Leith to Haddington, is likewise about thirteen miles, and a line drawn across this coal field farther west, would come to be much about the same length, which shews, that this coal field is about sixteen or eighteen miles long upon the line of bearing, and about twelve or thirteen miles broad in a line at right angles across the bearing of the strata; but it should be remarked, that we cannot determine the real length of this coal field upon the line of bearing, because the north-east ends of the coals immerge into the south side of the frith of Forth.

I have perhaps been a little tedious upon this head; but it is once for all. I know the extreme boundaries of other coal fields with as much certainty as this, but I will not meddle with them in the present investigation; because, I think it would only be travelling the same ground over again to no purpose, all the material circumstances being similar.

The

The one I have pointed out is near Edinburgh, and, therefore, the truth of every circumstance may, in future, be thoroughly investigated by young gentlemen who engage in these studies. And, moreover, the result of my enquiries about the Lothian coal fields establishes two important points in the natural history of coal, viz. First, that every coal field is of limited extent and dimensions, and that the coals crop out to the surface of the ground, or at least to the superficies of the strata, every where quite round the coal field; and, therefore, secondly, the coals do not stretch away under our high mountains, and emerge again upon the other side of them. The real extent of all other coal fields in the island may be traced out and determined as well as this of Mid-Lothian.

From Easter Duddingstone to Carlops, the crop, or outburst of the coals, trends towards the south-west; but from Carlops to the foot of the Moorfoot hills, the outburst, or crop of the coal, trends towards the south-east, at right angles to their former course. However, in this south-east line, from Carlops to the Moorfoot hills, other strata, of quite different quality from the coal metals, emerge from under the outburst, or crop of the coals and coal metals, and trend away towards the south-west, in the exact line of bearing which the coals lost at Carlops, which is the true line to
which

which the strata trend in general through this island ; and it is to be observed, that the strata of the mountain rocks are found immediately in full perfection of quality and regularity of strata when they first appear from beneath, and immediately to the westward of the coal metals, and the line of bearing of those foreign strata is immediately perfect so soon as they are seen ; from which circumstance, in conjunction with many others, it evidently appears to me, that the coals and coal metals were among the last formed of the strata which compose the superficies of our globe, at least in this part of the world ; but I will not enter upon such abstruse disquisitions here. It is my intention to keep as close as I can to the instructive parts of the natural history of the coals and the coal metals.

I imagine that I have already been abundantly particular and explicit in proving that the coals and coal metals do not push their way through beneath the mountains, and emerge again upon the other side of them ; and in proving that the coal fields are but limited patches, the extent and boundaries of which may generally be traced out and ascertained, an instance of which I have given in the coal field of Mid-Lothian.

As all I have yet produced upon that head is of the nature of direct and positive proof, I will

now beg leave farther to point out a few other circumstances which immediately relate to the subject, and may be considered in the light of collateral proofs of the double point under consideration.

With respect to the coals diving through beneath the mountains, and emerging again upon the other side, it is perhaps very rare, if ever, we find them upon the other side of a mountain, composed of strata altogether different from the coal metals, in the true line of bearing; and if such a thing should happen, there is yet, besides all that has been said upon this head, another substantial objection to their being the same coals and coal metals. I never yet saw, and I am persuaded that no other person has yet seen, the same class of coals and coal metals in any two fields, so distant from one another as upon the opposite sides of great ranges of mountains. Such classes of coal seams, and their concomitant strata, would be perfectly well known again by men of skill and experience, by their number, quality, thickness, position, or stations one above another, and by many other characters. In short, they would be as well known by an observing coal-master, as a family of children and domestics would be known by the master of the house, if he accidentally saw them arranged at dinner in some distant

tant part from home ; but the truth is, that we never see the very same coals, &c. in any two very distant coal fields, much less upon the opposite sides of ranges of mountains.

But, in order to throw all the light I can upon this subject, and to place it in as clear a point of view as possible, it may be proper for me to distinguish the difference between a real range of mountains properly so called, through or under which the coals do not pass, and such lesser hills as are frequently found dispersed here and there, within the limits of the coal field or coal country.

A range of mountains, properly so called, are generally composed altogether of various mountain rocks, that is, of such different rocks and strata as seldom or never accompany coal, and among which no seams of coal are ever found ; these mountains are generally of greater dimensions in height, breadth, and length than such lesser hills as are sometimes dispersed through the coal country. What I call the lesser hills, which are often found dropt here and there within the limits of a coal field or coal country, are generally composed of such rocks and strata as very frequently accompany coal ; and sometimes the coal seams stretch away in the line of bearing quite through these hills.

Such gentlemen, and even such philosophers and naturalists as are not proficient in this
silence;

science, may be led to imagine, from the rugged craggy appearance of some of these lesser hills, that they are composed of materials altogether foreign from coal; and as coal is frequently found upon both sides of such hills, they perhaps may be led to conclude, that the coals and their concomitants dive down and shoot away under the hills, and emerge again upon the other side; but this is one of those hasty conclusions, when too much is taken for granted, before all circumstances have been investigated, which are but too numerous in matters relating to the mineral kingdom. If they would take the trouble thoroughly to investigate circumstances, they would generally find, that although these hills should in some places exhibit externally a rugged and formidable appearance, they are nevertheless composed of such rocks and strata as are frequently found to accompany coal. Such, for instance, are many thick beds or strata of basalt, commonly called whin rocks, which are frequently found in the coal fields of the Lothians, Fife, and other parts of Scotland. Now, these strong beds of rock are not only found in the coal countries, or in the neighbourhood of coal fields; they are also frequently found both above and below seams of coal, and coal pits are frequently obliged to

to be sunk through them, as at Borrowstounness, Bathgate, &c.

It is remarkable of the basalt, as well as of some other very hard and strong rocks, that although they are found disposed in beds or strata, with other regular strata above and below them, yet the basalt is often found very thick and very irregular in the thickness of each stratum. In one place, a stratum of this rock shall not be above two or three fathoms thick, and farther forward upon the line of bearing, it shall be found two or three times, perhaps in some places more than six times as thick. The basalt frequently swell greatly in thickness, and rise up from a plain to a considerable mountain, as the beds of it advance in the true line of bearing.—The same phenomenon frequently happens to strong beds of the mountain lime-stone. I have in many places seen the lime rocks swell out, and dwindle again from two or three fathoms to more than a hundred fathoms thick.

An instance of coal seams, and their concomitants, stretching through some rocky rugged hills, may be seen in the Bathgate hills, in West Lothian. These hills in some places are remarkably craggy and rugged, and of considerable height and extent; nevertheless, they are entirely composed of coal metals, and several seams of coal stretch quite through the whole breadth of those hills,

hills, from side to side ; and some of these seams have not only been wrought upon both sides, but they have also been wrought up the sides, and in several places upon the summit of those hills.— There are in the structure of these hills, besides the seams of coal, strata of free-stone, blaes, and other constant attendants of coal, several beds of lime-stone, of the coal metal species; and there are also several strong beds of basalt, which in some places rise up to a considerable height, and give several parts of these hills a rough and formidable appearance, and I know that seams of coal rise up among the highest craggs of these hills.

I have already pointed at the columnar basalt to be seen in these hills, and, therefore, it is unnecessary to say any thing farther upon that subject here.

In the instance of the Bathgate hills, and of many others that might be produced, we evidently see that the coals do not dive away under the mountains, and emerge again upon the other side. If they pass through mountains at all, they stretch up to the summits of them, along with their concomitant strata,—are a proportion of the constituent parts of the composition or construction of such mountains, and the superficies or crops of the coal seams rise up to the day, wherever they stretch into or through such mountains.

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With respect to the supposition of the coal seams stretching away in the line of bearing, I know not where or how far, it may be remarked, that there are but very few coals as yet discovered in Ireland, although the numerous seams found in Cumberland and those of Ayrshire point towards that island, as well as those of Lancashire and North Wales, and many of them are known to immerge into the ocean upon the British side, but they are not found to emerge again upon the Irish side of the water. If these British seams of coal continued in the line of bearing, as many confidently assert, they should emerge out of the ocean upon the other side, and appear again upon the Irish shores, there being neither mountains nor hills by the way in the line of bearing to conceal them from discovery. I have not heard of any coals being found in the Isle of Man, which is much nearer than Ireland. But I need not insist upon this topic. The matter of fact is abundantly evident, even to ocular demonstration; and whoever examines circumstances in all parts of the countries he is best acquainted with, will see abundance of instances in proof of what I have advanced upon the subject.

This history of the strata of coal has been tedious, but I think it may be singularly useful. The knowledge of truth in all cases must be useful,

ful, and especially when it is likewise the knowledge of nature.

From the tenor of the above dissertation upon the disposition, stretch, and bearing of the strata of coal through a country, there is one very important lesson that may be treasured up by every person concerned, who is at pains to examine and investigate the subject, namely, that it is not prudent, that it is often dangerous, to lay out large sums of money in trials for coal at any considerable distance from the place where the coal is seen and known, upon the faith of the strata continuing the same stretch and line of bearing invariably; and that before we begin upon an expensive plan, we should procure a perfect history of the concomitant strata which are found above and below the coal; and if we fail to discover and to recognize them with sufficient certainty, we have good reason to suspect that the coal is thrown off its ordinary stretch and level, or out of its ordinary course or line of bearing, by some of the many accidents which I have described above. If they cannot find several of the particular strata which accompany the coal in the field where it is seen and wrought, and in the same order, one above another, as in the former field, it is quite out of nature to expect to find the same coal without them; and even though they discover strata which appear like them, it
will

will not do, unless they be really the very same, There is often a very near resemblance in the appearance and characters of particular strata in quite different fields, and sometimes in different places of the same field; yet there is always such difference either in the particular stratum itself, or in some of those immediately above or below it, as will be readily distinguished by a skilful eye.

This lesson may be of singular use to such gentlemen as are persuaded that there is abundance of coal in their estates, because their lands are situated in the line of bearing towards which the coals trend, which are now working at some distance, perhaps two or three miles off. The want of sufficient knowledge in these cases, frequently occasions many blunders, much needless expence, and subsequent vexation, when their sanguine, but ill-grounded hopes are frustrated.— They should either see the coal itself, or several of the known concomitant strata, before they make themselves sure of a coal which is wrought in their neighbourhood at a considerable distance, and where no coal is near to justify a presumption of its being in the place desired; they should either see the outburst or crop of some coal, or at least, they should see several of the known concomitants of a particular distant coal, which points that way, before they proceed to expensive trials, or indeed to any trials at all.

Several coal-masters and other gentlemen who have paid some attention to this branch of natural history, are of opinion, not only that the coals stretch away under the mountains, and emerge again upon the other side, but also, that the seams of coal dive down to the center of the earth.— They see that all seams of coal have certain degrees of declivity, excepting only that in some places the coals and their concomitant strata acquire a temporary flatness, or wave up and down with different dips for a short space; but they know very well at the same time, that these variations in the position of the strata are only fleeting changeable incidents, and that in general they all decline less or more towards one particular point; and, therefore, from this true observation, they conclude, that all coals dip down to the center of the earth: But although I acknowledge the justice of the observation, that the strata in general decline less or more in all coal fields towards some particular point, yet I cannot join with them in the inference. I am rather of the contrary opinion. I imagine that the coals and coal metals do not dive down to any very great depth; and I find myself obliged in this place to lay more stress upon my opinion than in any other part of this history, as I find it difficult to clear up the point to the conviction of every enquirer, by adducing obvious and satisfactory examples.

However,

However, I shall offer a few observations in support of my opinion, after premising, that with respect to the center of the earth, two or three hundred fathoms, or two or three thousand fathoms, are neither of them a great depth, in comparison of the semi-diameter of the globe. It is but very rare that we sink two hundred fathoms perpendicular into the surface of the earth, and two hundred fathoms, comparatively speaking, is but a superficial scratch, and, therefore, we are not enabled to form any judgment of this matter from the observations we can make below ground; and, as the question is merely curious, I shall not be very anxious to defend my opinion by the observations which I have made above ground.

I observed before, when treating of the bearing and declivity of the strata of coal, that some coal seams are known by real experience to crop out every way. I could produce many instances in point, but I incline to bring observations of this nature as near to Edinburgh as possible, where I hope that this branch of natural history will one day be publicly taught.

It has been remarked already, that the seams of coal, and their concomitant strata, in the north-west side of the Mid Lothian coal field, dip towards the south and south-east, and that the coals in the south and south-east side of the same field dip to the opposite side of the compass, viz. to-
wards

wards the north and north-west. This fact is commonly known upon the north side of this coal field, and it is obvious upon the south side of it, in the parish of Temple, and other places farther east.

Now this does not look like the coals dipping down to the center of the earth. It rather looks like their declining a little way down from the surface of the earth to a sufficient depth to be preserved fresh and good, even in full perfection, until the exigencies of society have occasion for them, and that when they have declined down so far, they then become quite flat, and afterwards rise again upon the opposite side of the coal field, with an opposite dip and rise, and so form a great trough, resembling a valley, which is one of the best similitudes of the position of the seams of coal in a coal field as can be imagined.

Let us suppose, that the middle or lowest part of the valley resembles the deepest part of the trough of the coal. There are in some extensive valleys several inequalities of surface, that is, little pieces of rising ground, higher and lower places, which resembles the waving of the strata of coal up and down, and this way and that, when they turn flat or horizontal; however, when we have quite crossed the valley, we always come to a sensible and a decided rise or ascent of the ground, which brings us out of the valley; and, from my
own

own knowledge and observation, I am clearly convinced that this in general is the true description of the disposition of the strata in every coal field, though perhaps it may not every where be an easy task to investigate all circumstances, so as to be enabled to prove the point to ocular demonstration.

Many more instances in point, however, might be produced, besides the Mid Lothian coal field, but I will only mention one, which is likewise pretty near Edinburgh.

The range of coals and coal metals which are found upon the north side of Dunfermline, and trend from thence by Halbeath, Sir John Henderson's colliery, and farther east in Fife, decline at Halbeath, &c. towards the north or north-west. There are a very great number of seams in the Fife coal field, which reach in length from Stirling to St Andrews, and I suppose that it is in some places about ten miles in breadth. There is no better coal in any part of Scotland, either hard or soft, than in Fife. The smithy coal of Balmule and Rosebank is the best in Scotland as yet discovered.

Now, all the seams in the south side of this fine and extensive field, dip with various degrees of slope towards the north or north-west; and, as has been observed of the Mid Lothian coal field, they wave up and down over a great extent
of

of country, and at last they rise again and crop out upon the north side of this coal field. If any should doubt the truth of this assertion, let them examine circumstances as I have done, and they will be thoroughly convinced. They may have an excellent opportunity of seeing this subject distinctly, and of clearing the point to their full satisfaction in the rivulet above the village of Dollar, and immediately below the magnificent ruins of Castle Campbell, where they will see the coal metals in the bed of the mill-lead, cropping out to the day, and dipping precipitately towards the south, and the strata of the mountain rock commencing and appearing immediately below the free-stone and other coal metals, and the very place where the different ranges of the coal metals and the mountain rocks come in contact, is there distinctly seen. Immediately above where the coal metals finally crop out, the rivulet emerges out of a deep, rocky, and impassable gulph below the old Castle, which place is every way a curious romantic scene.

The result of this investigation refutes by inference another erroneous opinion concerning coal, which I have often heard asserted with great confidence, viz. that coal is inexhaustible. That the fund of coal treasured up in the superficies of the globe, for the accommodation of society, is very

very great, I readily acknowledge; but that it is inexhaustible, in the proper sense of the word, I deny.

Some portions of some particular seams of coal may be situated so deep below the surface of the ground, that it may be impracticable for man to work out all the coal in such places, and of consequence all the coal in such particular spots never will be exhausted; but such a particular circumstance, and such a particular spot, does not imply that coals in general are inexhaustible. I very well know, and when I come to explain the real origin of coal, I will make it appear, that the source of coal, or the matter of which it was formed, though copious, was limited in quantity, and, therefore, the quantity of coal is also limited, and the real source and origin of coal may justly be produced as a sufficient reason why so many tracts of country, in many extensive regions of the world, are absolutely without any coal at all.

I have not the smallest doubt that the generality of the inhabitants of Great Britain believe that our coal mines are inexhaustible, and the general conduct of the nation, so far as relates to this subject, seems to imply that the inexhaustibility of our coals is universally held as an established

blished fact. The conduct of the public says so in plain enough language. If it was not a generally received opinion, would the rage for transporting coals be allowed to go on without limitation or remorse? But it is full time that the public were undeceived in a matter which so nearly concerns the welfare of this flourishing island.

If our coals really are not inexhaustible, the rapid and lavish consupt of them calls aloud for the attention of the Legislature, because the very existence of the metropolis depends upon the continued abundance of this precious fossil, and not only the metropolis, but also the existence of the other cities and great towns, and of the most fertile countries in the three kingdoms, depend upon the abundance of this valuable article; and, moreover, most of our valuable manufactures are in the same predicament, and, therefore, if our coal mines are not inexhaustible, it is high time to look into the real state of our collieries.

I feel in myself a strong reluctance against founding the alarm to my country in a matter of so much importance. I am but an obscure individual, of very little consequence in the world, and I have not the least doubt that I shall be severely censured by many for my presumption, and therefore I proceed with sensible remorse; but it is

is not guilty remorse ; on the contrary, my heart tells me, that were I to temporize with my own feelings of reluctance, and to conceal a truth which so nearly concerns the welfare of the community, for fear of incurring censure, my silence would be unpardonable. I could wish that I did not find myself under the necessity of publishing a truth which perhaps may be disagreeable to many individuals ; that there was the least foundation for supposing that I am mistaken ; and that it could be made appear with any shew of truth, that our coal mines are inexhaustible ; but, on the contrary, so far are our coal mines from being inexhaustible, that they are in many places already beginning to make quick advances towards being exhausted. I will not make use of much reasoning in support of this assertion. A few instances in point will be more convincing than a thousand arguments.

Mr Hume, in his History of England, and Mr Arnot, in his History of Edinburgh, place the first discovery of coal in this island about the middle of the thirteenth century, and it appears highly probable that they are right ; Mr Whitaker places it much earlier in his History of Manchester, but his reasons or proofs are vague and unsatisfactory ; and indeed such as are to be found in the present or former bed of every river, and in

numbers of the gravelly tumuli in all the coal countries; and, therefore, I lay aside his pretended antiquity of this discovery.

As Mr Arnot has been at pains to trace out this subject, and to place it in a clear point of view, I will beg leave to quote a passage from his History of Edinburgh, concerning the first discovery and use of coal in Britain, before I proceed to give any hints of my own about the present state of our collieries.

“ As the use of coal claims our attention, both by reason of its being the most valuable species of fuel hitherto discovered, and also an article of extensive and advantageous commerce, we hope a short digression concerning its introduction will not be considered as impertinent. We enter upon it the more willingly, because we are fully persuaded that the use of coal was first known in the period we have described, and that the date of its origin may be brought within a very narrow compass.”—
 “ Necessity is said, not unaptly, to be the mother of invention. Had our remote ancestors known that a valuable inflammable substance was lodged under ground, the abundance of fuel which wood and turf afforded, would naturally prevent them from digging into the bowels of the earth for that which its surface so amply supplied them.

“ Even

“ Even when wood became very scarce at the
 ‘ distance of several centuries after the discovery
 ‘ of coal, the manner * of working it was ex-
 ‘ tremely rude, the progress and extent of the use
 ‘ of it slow and limited. The statutes enacted by
 ‘ the Scottish Parliament, and the patents granted
 ‘ by the Kings, display their ignorance in work-
 ‘ ing coal, set forth strongly its decay, and guard
 ‘ anxiously its preservation. In the beginning of
 ‘ the sixteenth century, coal smoke † was deemed
 ‘ very pernicious, and even in the end of it,
 ‘ the use of coal in making ‡ of iron was
 ‘ hardly known in Scotland. If the progress in
 ‘ working of coal was slow, its first discovery was
 ‘ not very remote. Coal certainly was not dis-
 ‘ covered in the middle of the twelfth, and it was
 ‘ as certainly known in the beginning of the
 ‘ thirteenth century. In the *Lēges Burgorum*,
 ‘ which were enacted § about A. D. 1140, a par-
 ‘ ticular privilege is granted to those who bring
 ‘ fuel into boroughs. Wood, turf, and peats
 ‘ are particularly mentioned, but with respect to
 ‘ coal there is a dead silence. But, in the year
 ‘ 1234,

* Mary Parl. 9. c. 84.

† Northumberland Household Book, p. 21.

‡ Patent by James VI. A. D. 1594, in the Archives of the Earl of Balcarras.

§ Leg. Burg. c. 38.

‘ 1234, Henry III. of England * renews a charter
 ‘ which his father had given to the inhabitants of
 ‘ Newcastle, and in this renovated charter, he
 ‘ grants, upon their supplication to the persons in
 ‘ whose favour the charter was conceived, licence
 ‘ to dig coals upon payment of L. 100 a-year,
 ‘ which is the earliest mention of coal in the
 ‘ island. By the end of the thirteenth century,
 ‘ the use of coal was so much advanced, that it
 ‘ was frequently brought by sea carriage † from
 ‘ one port to another. But the first mention that
 ‘ is made of coal in any charter in Scotland is in
 ‘ a grant executed A. D. 1291, in favour of the
 ‘ Abbot and convent of Dunfermline ‡, of the
 ‘ privilege of digging coal in the lands of Pit-
 ‘ tencrieff, in the county of Fife.

“ Æneas Sylvius, who afterwards assumed the
 ‘ Purple under the name of Pius II. visited this
 ‘ island about the middle of the fifteenth century.
 ‘ He relates, “ That he saw in Scotland § the
 “ poor people, who in rags begged at the
 “ churches, receive for alms pieces of black
 “ stone with which they went away contented.
 “ This

* Anderton's Origin of Commerce, v. I. p. 111.

† Statuta Gildæ, c. 44.

‡ Cartulary of Dunfermline, p. 80. Advocates Library.

§ Ænei Sylvii Opera, p. 443.

“ This species of stone (says he), whether with
 “ sulphur, or whatever inflammable substance it
 “ may be impregnated, they burn in place of
 “ wood, of which their country is destitute.”

“ And Boetius, in his Description of Scotland,
 ‘ his native country, written in the beginning of
 ‘ the sixteenth century, says, “ There are black
 “ stones also digged out of the ground, which
 “ are very good for firing; and such is their in-
 “ tolerable heat, that they resolve and melt iron,
 “ and therefore are very profitable for smiths
 “ and such artificers as deal with other metals * ;
 “ neither are they found any where else (that
 “ I know of) but between the Tay and Tyne
 “ within the whole island.”

“ In China, it is probable that coal was disco-
 ‘ vered long before it was known in the western
 ‘ world.

“ About the middle of the thirteenth century,
 ‘ a noble Venetian, in his Description of China,
 ‘ observes, “ That through the whole province
 “ of † Cathay, certain black stones are dug out
 “ of the mountains, which being put in the fire,
 “ burn like wood, and when kindled, they con-
 “ tinue burning a long time, in so much, that
 “ if

* Boetii Scotorum Regni Descriptio, p. 10.

† Marcus Paulus Venetus, Purchas's Pilgrim. v. 3. p. 88.

“ if they are lighted in the evening, the fire will
 “ keep alive during the whole night. Many use
 “ these stones, although they have plenty of wood,
 “ the consumption of fuel in stoves being very
 “ great.”

“ It is curious to observe the similarity with
 “ which Marcus Paulus, Æneas Sylvius, and
 “ Boetius speak of the same matter.”

Upon the whole, we have little hesitation in
 fixing the discovery of coal to have been made
 between the middle of the twelfth and begin-
 ning of the thirteenth centuries.

Although it appears to be full 400 years since
 coal was first discovered in Britain, yet it is not
 above 200 years since it came into common use,
 and it is even less than 200 years since it came to
 be generally used in London.

Upon the first introduction of coal into Lon-
 don for common uses, one or two ships was suf-
 ficient for the whole coal trade; but from such a
 small beginning, they have gradually increased in
 number to several thousand sail of shipping in the
 coal trade, from the ports of Shields, Sunderland,
 and Blyth only, and some of them are of vast
 burdens, even up to a thousand tons and more,
 and many of them make several voyages a-year,
 fully loaded with coals.

Such

Such a prodigious number of ships continually carrying coals from Newcastle, Sunderland, and Blyth, not only to the metropolis and the other cities and towns of England, but also to almost all parts of Europe and America, must drain away an immense quantity of coal from the neighbourhood of Newcastle. Dr Campbell, in his Political Survey, says, that in his time they consumed 600,000 chaldrons of coals a-year in London alone; and, as the bounds of the metropolis is greatly increased, we may safely conclude that the consumption of coals in London is also increased, at least one third, if not fully doubled, since he wrote his Survey; and the consumpt of London, though great, is nevertheless but inconsiderable in comparison of what is carried from Newcastle and its neighbourhood round the coasts of Britain, and to all other parts of the world.

The run of coals from Newcastle and Sunderland has been so very great for above fifty years past, that we need not be surpris'd if we were to find the coals considerably wasted in the neighbourhood of Newcastle, so as to be in danger of soon raising the price considerably to the metropolis, &c.; and in fact this is the case. The coals near the sea in the neighbourhood of Newcastle are already wasted to a great extent, and to such a depth, that they cannot conveniently and profitably

bly go much deeper, without encreasing the expence prodigiously; and, therefore, we may safely conclude, that a considerable rise in the price must happen at no very distant period.

The price of coals is pretty high at Newcastle already, and I may venture to assert, that the price there would have been much higher, had not the coal trade from Scotland been a check upon them for a considerable time past, I believe I may say the most of the time since the Union.

Some of the coal pits of Newcastle are one hundred and twenty fathoms deep, and they have increased the powers of the fire engine so much, that it may be said it draws a river from that vast depth; but they cannot increase these powers much farther, without a considerable increase of expences.

These circumstances clearly prove, that coals are so far wasted near water carriage in the neighbourhood of Newcastle, that they are become already very difficult and expensive to winn; as a proof of this, they now work coals for sea sale near twenty miles up the country from Newcastle, which they bring down to the water upon waggon-ways, that is, roads composed of frames of timber, which are made and upheld at a vast expence.

It is not above thirty years since the Carron Company founded their great iron works in Scotland,

land, and yet they have already consumed an immense quantity of coal.

Several of the coal seams at Borrowstounness and Grange, in Scotland, are greatly wasted, and the works are pretty deep, and the coals are worked at considerable expence with large fire engines in several other places upon the banks of the Forth. The cities of Edinburgh and Glasgow depend upon the fire engine for their supply of coals, and yet they ship away from Glasgow all the coals they can get any demand for, without any apprehension of the future.

At Whitehaven, which chiefly supplies the city of Dublin, and many other parts of Ireland; with coals, they already work their coal at the enormous depth of more than a hundred and twenty fathoms; and, of consequence, great part of the coal easily come at is exhausted, and what remains must be worked at great expence:

I will only point out another place where the coals are exhausting rapidly, and the scarcity and dearth of them, I fear, will soon be felt by many of the commercial cities and industrious inhabitants of Britain. The island of Britain is famous in the earliest records of antiquity for the tin mines of Cornwall. The tin and copper mines of Cornwall are to this hour of great consequence to the manufactures and commerce of Britain; but the tin mines especially have been

worked so long, and, of consequence, are now so deep, that very little of that valuable metal can be raised there now without the fire engine, but alas! they have no coals in Cornwall. All the coals necessary for working the fire engine, and for their smelting furnaces, are brought by sea from South Wales. I do not pretend to be well informed either of the extent of the coal fields, or of the proportion of the coal already wasted in South Wales; but from such information as I could get, it appears that the coals there are wasting rapidly; and what will become of the mines of Cornwall when they are exhausted? I have been informed that the price of coals in South Wales is already so high, that several Cornish mines are now standing on that account, because they cannot be carried on with profit while coal is so dear; and if coal rises to a higher price in Wales, which very probably will happen in a few years, it will be equal to a prohibition from working most of the Cornish mines. When this event happens, what will become of many of our valuable manufactures, upon which much of our lucrative commerce depends?

This is a mortifying view of the subject, but I am afraid it is too just a representation, and yet, as far as I know, this interesting subject has never been considered in this light, nor has any person, public or private, to the best of my knowledge,
ever

ever taken the trouble to make a fair representation of this matter to those whose business it is to look into and to remedy such evils. There is no restraint upon the unnecessary consumption of those coals, nor of any other coals in the island, however many and important the manufactories may be which depend upon them.

The exportation of coal to foreign countries is now become a great trade, which has increased rapidly within a few years past. No doubt this trade is beneficial to some individuals, and also to the revenue; at the same time, we should reflect that this avidity for the pleasure of present profit has a deadly sting in the tail of it. We are now eagerly supplying other nations, and frequently our worst enemies, with those coals which the metropolis and our manufactories will one day stand in need of. And even now, the exportation trade has raised the price of coals so high as to be exceedingly inconvenient to many of our manufactories, and to many of the industrious poor, especially in South Britain.

If this is the case at so early a period from the first beginning of the general use of coals in this island; if they are so much exhausted, and raised to so high a price, in little more than two hundred years from the first beginning of the use of coals, and in less than one hundred years from the commencement of an extensive consumpt, what may

we

we suppose will be the price of them two hundred years hence ?

The continual increase of the coal trade, and of the general use of coals, is so great, that I am persuaded that the one half of all the coals that ever were consumed in this island and exported from it, have been raised within the last eighty years, as there was, comparatively speaking, but little coals used eighty years ago ; and, if this is true, it shows us how rapidly our coals are wasting, for it is certain that our coal works in many places are deep, the coal wastes extensive, the machinery and whole apparatus of the works very costly, and the coals, in maritime places especially, raised at a great expence ; so great indeed, that some coal works are carried on with loss.

The present rage for exporting coals to other nations may aptly be compared to a careless spendthrift, who wastes all in his youth, and then heavily drags on a wretched life to miserable old age, and leaves nothing for his heirs.

When our coal mines are exhausted, the prosperity and glory of this flourishing and fortunate island is at an end. Our cities and great towns must then become ruinous heaps for want of fuel, and our mines and manufactories must fail from the same cause, and then consequently our commerce must likewise fail. In short, the commerce,

merce, wealth, importance, glory, and happiness of Great Britain will decay and gradually dwindle away to nothing, in proportion as our coal and other mines fail ; and the future inhabitants of this island must live, like its first inhabitants, by fishing and hunting.

My natural history of the strata of coal may be disputed by such novices as are absolutely ignorant of the subject, but it cannot be disproved by such proficient in the science as will take the trouble to examine all circumstances ; but whether my history be disputed or not, the general facts which I have stated relating to the subject of our collieries and of our coal trade are indisputable. These facts are easily investigated. Accurate surveys can be made, and pretty near calculations of the coal to be had, and of the time it will last, when compared with what has been worked out of each coal field for a limited time past.

Now, if these facts shall, upon due examination, be found as I have represented them, I will leave it to disinterested well-wishers of their country to judge whether or not this subject deserves and requires the attention of the public.

I am no judge of the lawfulness or propriety of restraining the subject from the uncontrouled use of his property in this land of freedom ; but I clearly foresee, and can form some judgment of the fatal consequences to future ages of a too rapid

pid consumption of our coals, especially in the maritime parts of the country.

It is very well known to numbers of individuals, though perhaps not sufficiently well considered by the public in general, how much this nation is indebted to the mineral kingdom for the principal commodities which are conveyed round the globe in the numerous and extensive channels of our commerce.

The manufactories which prepare the materials and fabricate these commodities are exceedingly multiplied and various, and the number of hands employed about our mines, manufactories, and commerce is very great ; and it is an established truth in politics, that numbers of people well employed are the riches of a nation, and it is especially so in this case, as all the materials from the mineral kingdom are our own. Our other mines produce the raw materials of our various hard manufactures, but some of those materials cannot be raised out of the mines, and none of them can be prepared and manufactured without coals.

I have no abilities for nice and extensive calculations, or what is called political arithmetic ; however, if this subject was but duly attended to by the public, there are not wanting numbers who are capable of calculating, and of properly stating

stating the effects that a general rise of the price of coals would have upon our manufactures and commerce.

There are some plain facts, however, which appear to me very evident, and must appear so to every other person who takes even but a cursory view of these matters : Such as, for instance, *1st*, The lower the price of coals is, the cheaper the crude materials from the mineral kingdom can be prepared, and the cheaper the commodities can be manufactured from them : *2^d*, The cheaper our commodities can be manufactured, the better we are enabled to rival other nations in commerce : *3^d*, While we have coals enough at a moderate price, our manufactures and commerce will continue to flourish, but it is impossible that they should flourish any longer than our coals are plenty and reasonable ; because, other nations have greatly the advantage of us when our coals are either exhausted or too dear, as most of them have a much greater quantity of wood than we can boast of, or it would be our interest to have : *4th*, There are plenty of productive mines of all the British metals upon the continent of Europe, which they cannot now manufacture into such a number, quantity, and variety of excellent commodities as we can, on account of the plenty and excellence of our coals ; but when our
coals

coals fail, or are become too dear, then they can rival and exceed us on account of their extensive woods.

These facts are plain and self-evident, and, therefore, they neither stand in need of proof nor illustration; but they certainly call for attention, and it would require extensive knowledge, wisdom, and skill to form such regulations as will favour our own manufactures, and at the same time do justice to the British subjects and to the revenue.

I am really concerned for the metropolis and her younger sisters, when I consider what a great proportion of the Newcastle coal is already wasted in so short a period of time. The city of London, and the other cities and towns upon the east and south coasts of England, seem to me to have a strong claim, if not a natural right, along with our manufactories, to all the coals which the north of England can produce; and if proper care is not taken of their right in due time, they will too soon be deprived of it. There is indeed a pretty good fund of coal in Fife, and other places upon both sides of the frith of Forth, which may be sent to the metropolis, and to other places upon the east and south coasts of England; but there are a number of manufactories upon the banks of the Forth, which would be soon hurt by an extensive coal trade from thence, as such a
trade

trade would raise the price of coals there too high for such manufactories; and, moreover, the north of Scotland depends upon the frith of Forth for a supply of coals, and they seem to have a natural right to all the coal that can be spared from thence.

The mines of Cornwall and our copper manufactories, and such other manufactories in the west of England as use tin and copper, seem to me to lay claim to all the coals that can be spared from South Wales, as those mines and those manufactories are of the first consequence to great numbers of British subjects, and to some important branches of our commerce and revenue.

The city of Dublin, and many other parts of Ireland, depend upon Great Britain for a necessary supply of coals, even for culinary uses; and I hinted before, that the collieries of Whitehaven, from whence Dublin is chiefly supplied, are already very deep. However, there is a valuable and extensive magazine of coal for Irish consumption treasured up in the county of Ayr; and it is well for Dublin, and other parts of Ireland, that there are such magazines in Ayrshire and the north-west of England; and what would become of Dublin, &c. were these coals to fail? In that event, it might be said with propriety, that the Irish volunteers would blow a cold coal.— They little think of this when they begin to swag-

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Z

ger,

*There have lately been discovered
numerous & extensive treasuries of coal
in Tyrone & other counties in Ireland*

ger, disturb the peace, and neglect their proper occupations. They little think that Britain can starve them, knock up many of their manufactories, and ruin their cities for want of fuel.

When these matters are taken into serious consideration, and thoroughly examined, I presume it will then be thought by all the impartial and disinterested, that the less coal is transported out of Britain, the better for the nation in general, and the better for the manufactories of Great Britain and Ireland; and if foreigners get any coals at all from us, they should pay well for them by an increased duty.

Restraints imposed upon any established branch of our export trade, however salutary the tendency of them might be for the community in general, and of the national manufactories in particular, would, nevertheless, be interpreted by many as an infringement of the freedom of commerce, and of the liberty of the subject to dispose of his own property to the best advantage.

These matters are far above me; but they certainly merit the most serious consideration.

Another great difficulty occurs to me. Any restraints imposed upon the exportation of coal, would in some degree affect the revenue for some time at least. This difficulty seems to stand as an insurmountable barrier in the way of the future welfare

welfare of the people and manufactories of Britain with respect to cheap coals, and yet cheap coals is absolutely necessary for the welfare of both.

I am not politician enough to be able to suggest the proper remedy or succedaneum for all these difficulties ; but I will beg leave to observe, that, in my humble opinion, the coals of Cape Breton, and other parts of the western world in our possession, 'may be brought to make good the deficiency which the revenue might suffer by diminishing the export of coals from Britain. I am not sufficiently well informed of the history of the coals of Cape Breton, &c. to be able to state the circumstances relating to them with any degree of precision ; however, in general, it appears certain, that there is abundance of coal in that island, and that some of them were wrought by the French, and exported to their sugar islands.

Several navigators who had been at Louisbourg assured me, that the island abounds with coal to such a degree as to appear in the cliffs near the harbour ; but as none of these were men of science in this branch of natural history, their account was vague and unsatisfactory. Raynal's account of these coals, in his History of the Settlement and Commerce of the West Indies, is not more satisfactory than that of the ship-masters I conversed with.

In

In general, I learn from Raynal, that the coal lies in a horizontal position; that the French wrought it very near the surface without any hydraulic machinery, and even without any level mine or adit for draining off the water. It is probable that they began upon a stratum of coal in the face of one of the cliffs, and wrought it under cover, which is commonly done in Britain when coal is discovered in a cliff, or a ravine, and wrought upon a small scale.

Raynal's account of this matter, or any other information I have yet procured, gives no grounds for apprehending that any considerable quantity has been wrought. Such a work as Raynal hints at could have produced but very little coal that was worth raising at all. It is very well known to men of skill and observation, that such parts of every stratum of coal as are very near the surface of the ground, and as are naturally drained by the figure and disposition of the surface, is seldom good for any thing; and it seems to say much in favour of the Cape Breton coal, that those superficial works produced such as was worth the raising.

We are farther informed by Raynal, that a seam of coal was set on fire at Cape Breton, which burned with great fury. As this accident may seem very alarming to such as have not thoroughly investigated these matters, it may be proper

per to observe, that this conflagration cannot be of very dangerous consequence, to the coal. It will only consume the stratum that is on fire in the horizontal direction, until the fire arrives at one of the natural bars which are so frequently found to interrupt the regular stretch and bearing of the strata, known by the names of dykes, slips, &c. and there it will be stopped, for there the stratum of coal is partially cut off; and, therefore, the fuel of the conflagration must fail. It will only consume the seam of coal towards the dip or declivity of the strata to the water's edge, that is, so far down as the seam of coal is naturally laid dry by the cliffs and ravines, and other inequalities of the surface of the ground; and when it only burns down to the water, it is sure to leave the best of the coal; for real experience assures us, that the deeper coals are wrought down under water, the better they always prove. But it is proper to observe, that while a coal is burning near the crop or surface, it is not prudent to open any works to the dip upon that seam until the fire is really extinguished, because the fire will communicate with the works below when it gets air, and destroy the whole. However, in cases of necessity, the fire may be got under, and wholly extinguished, by corking and stopping the mines and shafts, and other apertures and air vents, and the

the effect will be hastened if a rivulet can be turned into the burning cavities, and such stoppages made as will confine the water to rise within the excavations. But if the external air can be perfectly excluded, the fire will be extinguished without any farther trouble.

As the island of Cape Breton is of considerable extent, and as there is a certainty of coal existing in the island, there is great probability that it may prove a valuable coal-field; and, moreover, there is but a narrow straight between Cape Breton and Nova Scotia, and the latter is situated directly in the line of bearing of the strata, and, therefore, it is probable that coals may be found in the maritime parts of Nova Scotia, where, it is said, that they really have been seen; and it is also said, that coals have been discovered in the island of Newfoundland; one or both of which places may turn out well, if properly tried: But supposing they should not, Cape Breton is of such considerable extent, that it promises a fund of coal equal to a very extensive exportation, and to the demands of the new world, for a long period of time, there being no room to doubt the existence of a number of seams; and it is highly probable, from what is related of them, that they are seams of a good thickness and quality.

This

This subject, therefore, appears to be of such importance as to merit an inquiry, whether or not it is proper for Government to encourage the working of those coals upon a large scale? In my humble opinion, it cannot admit of a doubt that it would be highly proper, and in the event of this new trade proving successful, it would soon become greatly beneficial to the mother country, by keeping down the price of coals at home, which would encourage her manufactures, and by drawing a revenue from the foreign coal trade.

It is not improbable that this scheme would meet with some opposition at first from the wealthy coal owners of Britain, as it might excite in them an apprehension of some abatement of their profits, as they now ship a considerable quantity of coal for the western world; and, it must be confessed, that if the existence and prosperity of the British empire was only to last for the short space of thirty or forty years, commensurate to the time that a set of men may be fit for pushing a lucrative branch of business successfully, and that at the end of that period all was to sink in oblivion when those men die, it would be very proper to hear them.

Upon such a supposition, it does not appear that any real good to Britain could be proposed from opening American or West India coals, because there is at this time a considerable quantity
of

of coal carried from Britain to the West Indies and America ; which branch of trade the American coal would interfere with and diminish. Self-interest acts upon the principles and views of present profit, and neither cares nor considers what will be the future consequence to posterity, provided it reaps the present advantage ; but God forbid our British rulers should at any time be so unconcerned about the present and future welfare of this commercial island, as to do or to leave undone what would hurt and injure the community in general, to gratify the avaricious views of a few wealthy individuals.

Upon this supposition of the coal of Cape Breton being opened, and proving as successful as there is reason to hope and expect, the coasts of the West India islands and of the continent of America are so very extensive, and the cities and towns upon the coasts so numerous and considerable, that the trade for those coals might be enlarged to such an extent as in time to bring in a revenue to the British Treasury, equal, if not superior, to the receipts from the whole coal trade of Great Britain, without laying too heavy a duty, or any way oppressing the western trade.

This event of itself is devoutly to be wished by every disinterested British subject ; but it is not this consideration that lies nearest my heart.

It

It appears to me certain, as an infallible consequence of the nature of things, that the commercial wealth and glory of this industrious and happy island must dwindle away by degrees, in proportion as coals become scarce or rise in price, and disable us from keeping down the prices of our manufactures, at least upon a par with our rivals; and, therefore, it is the saving of our own coals for our own use, and for the public good, that should be our chief motive to open the West India coal; and, moreover, it may not perhaps be improper to work out those coals as soon as possible, while they are in our power, lest we should not have them to work in time to come, if we let slip the proper opportunity, which seems to be now in a time of peace, when we have leisure to look after such matters.

We see, that with the help of our rivals, thirteen of the American provinces are made independent, and it is probable that they will soon be formed into a great empire. Many of the inhabitants of the principal cities of America have burnt British coals for a considerable time past, which they found cheaper than wood, after the country began to be cleared near the sea-coast, notwithstanding that the purchase, duty, and freight of coals from Britain must raise the price of them prodigiously to the Americans. I do

not know that there is much coal, if any, as yet discovered within the territories of the States of America ; and, therefore, it is to be supposed, that as they gather strength, and feel more the want of coal, they will cast an evil eye upon Cape Breton, &c. and envy us the possession of an island in their neighbourhood, which seems to be a vast magazine of coals.

Fire wood will soon grow scarce and dear along the coasts of North America, and manufactories will soon be established there, which cannot be properly and effectually carried on without large supplies of coal ; and, therefore, we must suppose that the very sense of their wants will alone be sufficient to make a conquest of Cape Breton for the sake of our coal. Such a conquest might be accomplished and secured before we in Britain could be well apprized of the preparations for it ; but if we had flourishing and extensive collieries, and a brisk coal trade going on there, in conjunction with our fisheries, it would be more worth our while to keep the island in a more sufficient posture of defence than it is at present. In short, I am of opinion that the sooner those coals are worked the better.

The certain knowledge of a fund of coal lying there unwrought, may be the means of losing all our West India possessions on account of those coals. It is not only the Americans that stand in
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need of those coals. The French, &c. are also much in need of them; and why may not the French join the Americans to conquer the rest of our American possessions, when they find by experience that the coal is absolutely necessary for both parties? We know what they have done, when they had no other motives, in procuring independence to our colonies, than to weaken us, and to appropriate our American trade to themselves; and why may they not do the same again, when they have the additional motive of securing to themselves our coal mines and fisheries, which are by far more precious to a manufacturing commercial people than gold mines?

If we could give the Americans a plentiful supply of coals from Cape Breton, it is presumed, that they would find this to be so great a national convenience, that it would induce them to extend their trade with Great Britain in preference to all other countries.

As matters now stand, no other nation can supply them with this precious and necessary commodity; and all people feel themselves happy when their wants are supplied. Our supplying them with coal, must, as a natural and necessary consequence, turn the balance of trade to our side. They will give the preference to our commodities for the sake of our coals, which no other nation can supply them with; and, therefore, we
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can keep the balance in our favours so long as we keep all our present possessions, and make a good use of them.

It has been said that there are coals in Canada, which I cannot disprove ; however, as far as Professor Kalm of Sweden had an opportunity of viewing the superficies of the strata in that country, there is not the least appearance of coal in Canada : And his account of the strata, which he saw in a journey from New York to Montreal, along the margin of some of the lakes and rivers, and along a considerable part of the river St Lawrence, is sensible, judicious, and satisfactory ; but Mr Kalm saw not the least symptom of coal among the strata which he viewed in Canada.

I am fully sensible that my information is not so perfect as the magnitude and importance of this subject deserves ; but I, nevertheless, think it my duty to communicate such hints as are in my power ; and however imperfect my hints are, I cannot help thinking that their great importance merits the attention of Government, and this attention will produce proper enquiries, which will enable them to investigate the truth of the facts which I have hinted at ; and such enquiries will give them the knowledge of many circumstances relating to this subject, which at present are out of my reach.

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The farther I look into this subject, the more interesting it appears. The existence of abundance of coal in the island of Newfoundland, is generally understood to be an established fact.— This is still a more interesting situation for coals than Cape Breton, on account of its vicinity to the great fishing bank. Cape Breton may be called the key of Canada, but Newfoundland is the asylum and defence of the cod fishery; and the importance of this great nursery for sailors is of the first consequence to a maritime and commercial nation, whose natural and surest defence is her naval force.

In the light which this subject appears to me, it is to be wished that the coals of Newfoundland, as well as those of Cape Breton, were worked out by us.

An extensive and successful coal trade at Newfoundland and Cape Breton, would produce such an increase of commerce and revenue, as would make our possessions in the west a great and constant object of care and attention. Our coal ships and other trading vessels would be continually traversing the coasts of the islands and continent of America. They would have something to do in every creek and harbour, north and south, which would give us perfect intelligence of what is going on in all the regions of the new world; and,

and, therefore, we could never be surpris'd ; and, as a consequence of the increase of commerce, we should always have a greater naval force in the West Indies than present circumstances require.

The Americans have plenty of timber for ship-building, and for charcoal to smelt their own iron ores. They have plenty of good land fit for raising hemp for cordage and sail cloth ; and abundance of these articles in perfection will put it in their power to build ships of war at a cheaper rate than we can do ; and it is vain to imagine that they will not some time or other avail themselves of the advantages of their situation, and of the natural productions of their country, and of the fertility of their soil ; and it is as vain to imagine that they will not cast an evil eye upon our western coal mines and fisheries when they have fully settled their form of government, and feel their own strength, and their want of our possessions for the farther increase of their manufactures, commerce, and wealth, and the farther aggrandizement of their power.

When Government is fully satisfied of the value and importance of the West India coals, of course it becomes a serious question, what is the most proper plan for opening and working those coals, for the interest of the nation and of all concerned ?

A few hints upon a subject of so much consequence from a professional man, cannot be thought unreasonable.

In discussing this topic, we presume to suggest, that, in the first place, it is necessary for Government to explore and discover these coals, and lay them bare for the inspection of British coal masters or companies, and with this view, the first thing to be done, is to employ a prudent man of abilities and skill in the theory and practice of the coal business; to survey the West India coals and coal fields; to make such trials upon the coals already discovered, and those he may discover, as may be necessary to ascertain the thickness, quality, and situation of each stratum of coal that may be judged worth attention; and to make out a full and substantial report of all the material circumstances relating to each coal, for the information and use of Government, and of such gentlemen and companies as may wish to look into this interesting subject.

As far as circumstances can be investigated, his report should give a satisfactory account of the quality and thickness of each seam or stratum of coal; of the number of workable seams in each coal field; of the roof and pavement of each stratum of coal, and the other concomitant strata situated above and below each coal, so far as they can be seen, and of the slope

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or inclination of the several coals from the horizontal position. He should consider the ease or difficulty of sinking upon, and of winning and working each stratum of coal; what machinery will be necessary for that purpose; the distance from a good harbour or shipping place; the ease or difficulty of conveying the coals to the shore, and of shipping them; and the present condition and necessary improvements of the several descriptions of shipping places should come under his consideration. He should calculate and report his estimate of the expence of opening and winning such a seam or seams of coal in Britain to a proper depth, and upon a proper scale, to be ready to work with a sufficient number of colliers, including the necessary machinery, and how much per ton is commonly paid the colliers in Britain for working such seams of coal. Allowance must be made by those hereafter to be concerned between the expence of such works at home and in the West Indies. In short, he should consider and report every thing that is necessary and proper to be known for the information of all those concerned, and the information should be very complete and particular when the subject is so remote, and is of such consequence to the commerce, wealth, and power of the British empire.

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When this report is made and considered by Government, suitable encouragement should be offered to gentlemen and to companies of character, stock, and abilities for such undertakings, to open and work some of those coals. It might be prudent for Government to give some aid at first to the undertakers; but such works would not thrive if carried on at the public expence,—they must be carried on by frugal and skilful undertakers, if we would expect them to succeed; and it will be necessary for one at least, and a skilful one, of those concerned, to be always upon the spot.

The first undertakers should be allowed a sufficiently extensive coal-field, and every reasonable privilege and indulgence; but they should not have a monopoly. Other adventurers should have room to employ their skill and capitals in this line of business in the west as well as in Britain. Monopolies seldom do much good. The views of monopolists are always too selfish and confined to be of extensive utility and public benefit.

Newfoundland, Cape Breton, and the peninsula of Nova Scotia are all in the true line of the bearing of the strata of coal, and others in the same parallels of latitude in other countries.—The strata of Great Britain, and those in the same parallels of latitude of other countries, trend from north-east to south-west, or nearly

so; and, from viewing the map, it appears, that Newfoundland, Cape Breton, and Nova Scotia are situated in this line of bearing; and, therefore, it is probable, that the same coals and coal metals stretch through these three different countries. There seems to be a certainty of plenty of coal in the two islands, and it is probable that the coal of Cape Breton stretches through the narrow straight into the peninsula of Nova Scotia, which is but a short distance.

The discovery of abundance of good coal in these three countries will give ample room for a number of undertakers: But supposing they were only found sufficiently good and plentiful in one of the three countries, there will still be room enough for a number of adventurers, and for a very extensive coal trade. How many different collieries of great extent are wrought in the two counties of Northumberland and Durham in England? and most of the coals of those counties are shipped off in the two ports of Shields and Sunderland. The populous sea coast of North America is so extensive, and the cities and sea-ports upon that coast are so numerous and flourishing, that there is no room to doubt of a sufficiently extensive demand to excite the activity and exertions of a number of adventurers in the western coal trade, besides the demand of the Carribbee Islands,

Islands, which of themselves are sufficient to create a brisk trade.

In the event of a brisk coal trade in the West Indies, Halifax or Louisbourg will soon become a famous mart, the staple of a great and extensive commerce, which will be created by the coal trade, and which will increase and flourish in proportion as the coal trade increases. Canada and Nova Scotia will share with the mother country the benefits of the new commerce of the west. A new and powerful spring will be given to the agriculturists. Their rich and extensive soils will receive the highest improvements, by supplying with provisions the numerous shipping and increased population which this new commerce will soon create.

Commerce gives the means and necessary aid for improvements in agriculture; but agriculture itself is the foundation of the commerce and prosperity of all nations. Agriculture gives to commerce men, provisions, and a great part of naval stores, and commerce supplies the means of improvements in agriculture. If Canada and Nova Scotia were favoured with these aids to improve their lands, the rich soils of those countries might soon come to supply Great Britain with all her naval stores. The woods of Canada and Nova Scotia will supply masts, yards, and tar, and their fertile soils will supply abundance of hemp,
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when they are enabled to advance the improvements of those soils. With respect to iron, there is now a considerable quantity made in Great Britain; and, to my certain knowledge, we have abundance of the raw materials for making any quantity that might at any time be desired. If a small encouragement was given for the making of iron at home, and some discouragement to the importation of foreign iron, our furnaces and blast-furnaces would soon increase to such a degree as to produce a sufficient quantity to answer all the demands of agriculture, manufactures, and shipping; and this regulation would have a direct tendency to enrich the nation, by keeping the money at home in circulation which now goes abroad to enrich other nations, and by employing great numbers of our own people to work upon our own materials. Our own iron manufactories certainly merit the public attention.

The British coal trade is well known to be an excellent nursery of able and hardy seamen. Few naval scenes in the world, if any, are more active and more constant than the coal trade from Newcastle and other parts of Britain; and it is where they are constantly employed in rough and dangerous seas, like the coasts of Britain, which always require hard labour, that able and hardy seamen are bred; and these, on board our ships of

of war, under able commanders, are the glory and defence of the British dominions.

The coal trade of the west, when it is improved, and the other branches of trade which it will create or increase, will employ and breed many thousands of good and hardy seamen : Our dominions in the western world will then become active and flourishing upon the American seas like the coasts of Great Britain, and our mercantile shipping will form a bridge of ready communication from the old world to the new.

But the harbours of Cape Breton and Newfoundland being frozen up during six months in the year may be considered as a great discouragement to this coal trade. The sailors employed in it cannot afford to lie idle during the winter half of the year, when no other employment is to be had, nor can the ship-masters afford to lay up their vessels so long in this dead season, when they cannot be employed at the fishing. The coal-works will require to be carried on constantly, to prevent the works, the materials, and machinery from falling to ruin. The colliers must be constantly employed, or paid for going idle, and habits of idleness will soon spoil them, and take away the power and inclination to work. If they work constantly for half a year without any consumption of the coals, they will accumulate to such a degree as to become troublesome, or they will

will spoil and inlake upon hand ; and, therefore, it will be necessary to ship off some coals in winter. When the winter is fairly set in, and the snow fallen, the weather is generally serene and pleasant, though cold during the rest of the winter in North America. We presume that it may be practicable during this settled weather to ship off some coals from the outer edge of the ice. For this purpose I would advise that the coals be carried out upon the ice to the shipping in a sort of boats or lighters, which may be drawn along the ice, fixed in a frame to move upon four wheels, or in the manner of a sledge. A windlass upon the shore, and another on board the ship, would draw this vehicle to and fro with a line upon the ice very expeditiously, provided the distance is not too great for the line to reach; in that case it must be drawn along by men or cattle. If the ice should happen to break at the outer edge near the end of winter, the boat-form of the carriage will secure it from sinking. If a ship can get out loaded to the open sea, she will find no difficulty in sailing southward, where the ports are always open. In a country so cold as Cape Breton, &c. where the frost is so intense, and of so long a continuance, it may be necessary to have substantial buildings raised over the coal-pits, and over the engines and other apparatus, where fires should be kept burning during the severity

verity of the weather. If such precautions are neglected, all the machinery will soon be frozen up and rendered useless for a long time, or be in danger of breaking to pieces in a moment if employed. All the masonry about the collieries must be done in summer, and care should be taken to build none when frost appears, and in such a country it will be very necessary to build with hot lime, that is, with lime newly slaked from the burnt lime-shells, which should be immediately mixed with sand and used before it cools ; and all that is slaked and mixed each day must be wrought up before night to prevent its being touched with frost. Mortar once frozen will never take band. This caution should be carefully observed in all buildings in those countries, especially in the garrisons and harbours.

But whatever may be the fate or the success of the American coals, it will not lessen the consequence of our own, nor the necessity of looking into the real state of our collieries, because it is of the utmost importance to the metropolis, and our other trading cities and towns, that there should be a certainty of the continuance of a plentiful supply of fuel at a moderate price. It is of the utmost importance to the prosperity of our manufactures that this fuel should be cheap ; the prosperity of our commerce immediately depends upon our manufactures ; and both must dwindle
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and decay in proportion to the scarcity or the high price of our coals.

It is of great consequence to our manufactories that coals should be plenty and cheap near the site of such as are already established, and where new ones are to be set agoing ; because, in most instances, the crude materials will not admit of being carried to the coals, and, therefore, the coals must be carried to them ; or, in other words, remote country places, at a great distance from the sea, will not answer for the site of most of our manufactories, and, therefore, it would greatly injure them to have the price of coals raised too high in maritime situations, where such manufactories are and should be established and carried on ; and they will too soon be raised high, if some proper regulations are not made in time to prevent it.

I do not know that the nation is much enriched by the money our coals are sold for in foreign countries, but I know that the increase and prosperity of our manufactures and commerce enriches the nation, because our own productions are thereby used to the best advantage, and our own people are employed ; and it is the number of people well employed that brings solid riches to all nations ; and I apprehend that it is yet practicable to increase our manufactures considerably.

I know certainly that in many places our metallic mines are not worked to the extent to which they might be carried on with profit; but dear coals must throw a prodigious damp upon mining, because the steam engine is now become necessary to mining at any considerable depth, which cannot be worked without cheap coals, nor can they afford to manufacture the crude productions of the mines if the coals are too dear.

There is much money sent out of the nation for bar iron, and yet we have plenty of materials at home for making iron: And I can prove to ocular demonstration that there is great abundance of the richest iron ores and iron stones to be had in Scotland especially, which can be raised at very moderate expences, where coals are also abundant and reasonable.

A greater number of blomaries would increase the number of useful manufactures, and the national advantages of the increase of useful manufactures is a subject which has been frequently explained; and, therefore, it would be idle and impertinent in me to proceed any farther, than barely to state these brief hints relating to the connection and dependence of our manufactures upon coal. But I hope to be pardoned for saying a few words more about the necessity of encouraging manufactures with a view to employ a greater number of hands.

There are very loud and just complaints of a general dissolution of manners, of thefts and robberies, and of emigrations to America. It deserves some enquiry, whether or not there is any fault in the police of the country; any public error or neglect which operates as the cause of these evils? It too frequently happens that the great and wealthy men of the world know very little about the state and circumstances of the industrious poor, even upon their own estates. Some of them never saw their own estates, unless perchance they may have cast their eye upon the plan for a moment! As I live in the industrious part of the community, and live by industry, I believe that there is often a want of employment. I know that great numbers here in Scotland are either forced to beg or emigrate for want of employment, even in the most improved stirring parts of the country, where most labouring work is to be had: I frequently see numbers every day seeking work which they cannot get; and when I reprove a sturdy beggar for being idle, he tells me roundly, that he cannot get employment.

The idle of all ranks and denominations are generally more mischievous than the busy, and their example has a malignant epidemic influence in corrupting others, and the idle poor especially; and such as have wasted their fortunes, or
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never had any, become the most dangerous and the most destructive nuisance to society.

Now, if there is such a general want of employment for numbers of the (would be) industrious poor in the Lowlands of Scotland, where improvements in agriculture, manufactures, and the useful arts are advancing rapidly, what must be the consequence in the Highlands, which, for the most part, are not capable of such improvements? The case of the poor Highlanders is desperate indeed! Though not a Highlander myself, I have been nearly all over that country, where I have seen such scenes of misery and want as would soften the most obdurate heart, and draw a tear of compassion from the eye of the pitying beholder; and all for the want of employment!

I have seen near two hundred people, old and young, in one glen, where ten or a dozen were equal to all the real or possible business of the spot, which was not capable of improvement; how then were the rest to live? how were they to procure food, where nothing could be done to earn it, or to raise it where none could grow? The Highlanders have been blamed for emigrating to America, and they are called lazy; but what can they do? All poor people in all poor countries are lazy, merely for want of the means
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and the habits of industry. Give them profitable employment, and they will become industrious.

Thousands of the Highlanders walk three or four, and some of them five or six hundred miles, going and returning, every harvest, and work near two months in the Lowlands, and in England, to earn twenty or thirty shillings, which go to eke out the profligate luxury of his landlord in London or Edinburgh; and this they repeat every year: Is this a proof of their laziness! Their country in general is not capable of much improvement in agriculture, nor can it be the site of manufactories for want of food. Some little might be done at Fort William, and in some parts of Argyleshire, in woolen manufactories for coarse stuffs, and the woods might be profitably improved in Ross and Inverness-shires; but all other improvements, excepting the fisheries, would require but few hands. In the fisheries only is there a prospect of plenty for all as the reward of industry. The fisheries will give present food to all of both sexes, and of all ages, with the well founded hope of future profit.

But I am afraid that our schemes for the improvement of the fisheries, will mar the prosperity of them, and squander away the public money upon unnecessary projects. I do not see the necessity of beginning with building towns; but I see the necessity of beginning with building granaries

naries and storing them. Build granaries in all the proper situations which the herring frequent, and where vessels can lie safe, and go easily in and out, and store these granaries well with salt and tree, and materials for nets and boats, and whatever else may be necessary for taking and curing fish. Give the people of the country a little assistance at first to prepare nets and boats, to be in readiness by the time the herring make their appearance. Give them at each station one or two experienced fishers from the north of Scotland, to learn them to make and bait their lines, and to take and cure cod, ling, &c. in the intervals of the herring fishery, and I will answer for it that the Highland Fishery will soon be improved to give plenty and happiness to the Highlands, and to be the glory and wealth of the nation.

There are plenty of men in the Highlands, who are naturally hardy and addicted to the sea. Teach these to take and cure all sorts of fish in the best manner, and give them some assistance at first to set them a-going ; that is, furnish them upon account, and the best security they can give, with salt, casks, and other necessaries, and they will thrive.

Of all the methods in the world of doing good to the industrious poor, there is none so effectual and beneficial as aiding their own exertions, and assisting their efforts to support themselves ;

selves ; and if this is properly done in the West Highlands, the fisheries will be successful, and the Highland fishers, and such as supply them with necessaries, will soon build towns for themselves, without any public aid but the fruits of their own industry ; and it is very necessary that it should be so, because all the public money that can be raised will be found little enough to build and store a sufficient number of granaries, which will require an immense sum ; and till this is done, the improvements of the fishery is not begun, although twenty towns were built. If you begin with building towns, they will be peopled by knaves, idle schemers, and whisky drinkers ; not by fishers, whose towns are their vessels or temporary huts, which Highlanders can erect in two hours. The towns will frustrate the hopes and good intentions of the public ; the public money will be wasted, the scheme ruined, and the fisheries left unimproved ; which God forbid !

I sincerely wish that men in power may be wisely directed to begin and proceed upon the best plan to improve the fisheries, for the relief of that miserable country, and for the good of the community in general.

There cannot be a more humane and benevolent action than to relieve thousands from extreme want and misery, and give them plenty and happiness ; and, eventually, it must entail everlasting fame,

fame, as it cannot fail of increafing the glory and wealth of the nation, but by proceeding upon a wrong plan.

A fuccefsful coal trade at Cape Breton, and fuccefsful fisheries at Newfoundland, and over all the extended coafts of the Highlands and Ifles of Scotland, would employ above a hundred thoufand hardy feamen, which would greatly increafe our ftrength and revenue. What a glorious profpect for a maritime and commercial people, whole wealth and bulwark is the fea!

It appears to me a matter of importance that country gentlemen fhould be inftructed in the indications and external appearances of coal, and efpecially fuch gentlemen as have landed property in coal countries. I have no doubt that many fuch will be glad to have the true and moft infallible fymptoms of coal pointed out to them, and diftinguifhed from the falfe and doubtful.

Some of the gentlemen whole eftates lie contiguous to certain coal-fields, will no doubt have coal in their own grounds, and others will be confident they have coals, whether it really is fo or not, for it frequently happens that thofe who are wrong, or ought to doubt, are nevertheless the moft confident. I will, therefore, for the inftruction of all concerned, make fome enquiries about the appearances of coal, and I will carefully

fully endeavour to distinguish the true and infallible from the false and doubtful. It may be said with truth, that coal itself, in some form or other, is the most infallible appearance of coal; but this is too general. I will point out a few of the particular appearances of it, several of which have already been taken notice of and described in this history.

In order to enter properly upon this branch of enquiry, let us go back and look to the various sections of the strata of coal, and their concomitant strata, which I have already pointed out in the rivers and rivulets of Mid-Lothian, &c. and likewise to the various sorts of strata which I have shown to be the immediate roof and pavement of coal. We should also go back and examine my history of the disposition, bearing, and declivity of the strata of coal, and their concomitants, where it evidently appears that the seams of coal, and such strata as accompany them, all crop out to the solid superficies of the globe somewhere or other.

This foundation being laid, we can proceed upon pretty sure principles in our search for coal. It being once understood that the one side at least, if not both sides of every seam of coal, rises up to the surface of the globe, and crops out somewhere, it is our business to go to such places where the superficies of the strata have a chance
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of being discovered ; as, for instance, to the rivers, rivulets, gullies, rocks, and ditches, in some, or all of which, we may get a view of the prevailing strata of the country ; and if they are of the class of coal metals, we are so far encouraged to proceed.

But I will beg leave to repeat here an observation which I made before, viz. that there may be, and certainly are, several species of the coal metals, or of such as exactly resemble those that accompany coal, in several places where no seams of coal are to be found. Such, for instance, are several varieties of the white and of the red free-stones, &c. ; but, on the contrary, the black and bluish blaes and soft coal tills, in which there are frequently found balls of iron-stone, and the grey bands, or greyish thin strata, of a flaggy stone, in the composition of which, and often between the beds, there is found a small quantity of the substance of coal ; these are seldom or never seen but in a coal field or in a coal country.

In working free-stone quarries in a coal country, there is often seen blackish beds of a coal-like substance between the strata or beds of stone, and there frequently appear small quantities of real coal in the heart of the stone when broken. These symptoms are not found between the beds, nor upon breaking the free-stone, in countries

where there is no coal ; and, therefore, where these symptoms are found, they are so many signs of the coal neighbourhood ; but it is impossible from these alone to know how near or far off you are from a stratum of coal ; and, therefore, it is necessary for us to proceed a little farther in our search.

I have laid it down as an established fact, that the seams or strata of coal rise up to the superficies of the globe as well as all other strata, only they do not always push up so boldly to the very surface of the ground as many hard stones and other indurated strata are found to do ; but, on account of the tender and more friable texture of the coal, the superficies of the stratum is often mouldered down, and lies concealed under a thicker or thinner bed or cover of clay, gravel, sand, or earth ; However, the superficies of the seam of coal is frequently discovered where the concealing substances which covered it are washed off the face of the strata by rivulets, or are cut through by ditches, &c. Where the cover which conceals the coal is washed off, or any way cut through, the stratum of coal is sometimes laid bare, so as to be seen distinctly, but more frequently you can only discern some more obscure and imperfect appearances of the outburst or crop of the coal, such as small bits or grains mixed with the soil. When you are searching a ravine,

a rivulet, or gully, and discover grains or small bits of coal in any part of the slope, such grains point out the seam of coal to be higher up than where you stand. If you discover a quantity of soft, black, soot-like matter, you should dig in it, because it is very probable that you have found the crop of a seam of coal, as the superficies of some coal seams are dissolved into a soft undistinguishable mass, resembling black friable earth, in which sometimes there is not a grain of coal to be seen immediately at the surface; nevertheless, if you dig down a little in it, you will soon discover grains and bits of coal. When the surface cover of clay, sand, or earth is so thin that the superficies of the strata are touched in cutting ditches, and by the plough, the outcropping of a seam of coal is in that case frequently discovered by grains of coal of different sizes, or a quantity of black sooty stuff being thrown up by the spade or the plough. Perhaps at first this black matter will not look like coal; but if you examine it narrowly, and especially if you dig in it, you will soon find small bits of coal, though perhaps at first no bigger than pease. In digging down for trial upon a real or supposed outburst or crop of a seam of coal, it is necessary to have some knowledge of the declivity of the strata in that ground, both with respect to the point of the compass towards which they slope, and also of the

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the degree of declivity, in order to know how to push the cut you are digging towards the dip, otherwise you may soon cut through and overshoot the appearance of coal, and find nothing below but clay or rock, or some other earthy or stony matter, without the least vestigia or appearance of coal.

It is very well known in experience, that the crop or outburst of some coals spread upon the surface, sometimes to a considerable distance from the real and solid crop of the coal where the seam is to be found betwixt roof and pavement, even upon level ground; and where there is less or more declivity, it then spreads still farther from the solid stratum.

I have frequently seen the vestigia or appearance of a thick seam of coal spread upon the surface, beneath the upper soil, twenty or thirty yards from the real seam, where the surface of the ground had a considerable declivity. The side of this vestige or appearance of coal next the solid seam, is sometimes as thick as the seam itself; but it gradually wears thinner and thinner as it recedes or spreads away farther from the seam; and it also grows worse and worse, or the more unlike coal the farther from the seam. The side of this vestige, next the solid stratum, chiefly consists of the debris or rubbish of coal broken small. A little farther from the seam, it
consists

consists of very small grains of coal mixed with a black sooty-like matter; and still farther, nothing appears but sooty matter, resembling black friable earth or clay, especially if there is any clay either in the soil or under it; and, at the extremity of the vestige, I have seen it dwindled away to an inch or less, of a blackish soft substance, like a thin stratum of clay. Where the surface of the ground has the least declivity, the vestige or appearance of coal is sure to spread downwards from the seam, be the slope of the strata which way it will; and the greater the declivity of the surface, the farther down we may expect to find the extremity of the vestige.

When a coal crops out upon level ground, we shall not find the vestige of it spread out so far from the seam as upon a declivity; and as the vestige is not spread out so far, neither will it be found so thin at the extremity upon a plane as upon a declivity. When a stratum of coal crops out upon a plane or level field, there is one remark to be made concerning the vestige of it, which is different from the declivity. Upon a plane, the vestige of the coal always spreads out in a right line forward from the acclivity or rise of the seam of coal.

But I must be more explicit. Let us suppose then that the stratum of coal declines or dips with an easy slope towards the south-east; in that case,

case, the rise or acclivity of the seam comes to be towards the north-west, and in that case the vestige of the coal will be found a little way from the solid seam farther forward towards the north-west; and, therefore, when a vestige of coal so inclining is found upon level ground, and you have cut through it, and found different soils below, you must then turn your face towards the south-east, and dig away in the vestige, keeping your cut down to the clay or rock, or whatever matter you find immediately below the vestige of the coal, and by following the vestige or appearance of coal towards the real dip of the seam, it will not be long before you will find the solid seam between roof and pavement.

This circumstance of the vestige or crop of the coal spreading forward in a line with the acclivity of the seam, makes the knowledge of the declivity of the strata in that place very necessary, as without it you do not know which way to push or advance forward with your trial for the coal, although you should find a vestige or lively appearance of it. But in finding some appearance of coal upon an inclining plane field, or in the side of a glen or dingle, or any other description of sloping ground, the case is quite different. To whatever point of the compass the dip and rise of the strata should happen to be, the vestige of the coal is sure to slide down the
slope

slope of the ground, and we are sure to find it spread thin in proportion to the precipitance of the slope, and the distance from the solid crop of the seam of coal.

When gentlemen wish to know if there are appearances of coal in their estates, they should, in the first place, make themselves well acquainted with the appearances and characters of the various strata which commonly accompany coal. The characters and appearances I have described above : And, secondly, they should make themselves acquainted with the various symptoms and indications of a seam of coal, which I have now under consideration. When they have acquired these two branches of knowledge, their business is to walk up and down, and carefully to examine all the ravines, gullies, rivulets, scars, and ditches in their estates, with such rocks and precipices and other places where the superficies of the strata may be seen.

I have said above, and I know it to be truth, that there are few amusements more pleasant, entertaining, and agreeable, perhaps there are none that soothe, enlarge, and elevate the mind like researches of this kind. It is in these scenes that we discover what the solid superficies of our globe is composed of, and how it is formed ; and the variety which we behold, and the discoveries which we make, are a never-failing
source

source of pleasure and entertainment to an inquisitive and intelligent mind; and it is in these broken scenes of nature that we have the greatest chance of making mineral discoveries of various kinds, and particularly discoveries of coals and quarries.

Sometimes the crop and bearing of strata of coal run parallel to one of these ravines or gullies for a considerable length of ground, and sometimes they cross the glen or dingle in a right or a diagonal direction. When a stratum of coal crosses a glen in any angle whatever, there is a probability of discovering the crop of the seam or some indications of it, either in the bed of the rivulet or upon one side of it.

It is not uncommon, in some places in coal countries, to find the superficies of the strata washed clean by a river or rivulet *in statu quo*, that is, to find the seam or stratum of coal in its proper regular position in the solid superficies of the strata, at full thickness and in perfect form betwixt roof and pavement, dipping towards the same point with the ordinary declivity of the strata in that place; but it is more common to discover in such places only some appearances of coal, which frequently require knowledge and acuteness to discern, with skill and judgment to make a proper use of the discovery.

I have all along in this history inculcated the necessity of some proficiency in the natural history of the various strata which compose the structure of the superficies of our globe, in order to qualify us for researches of this kind.

It is necessary for us in the present case to have some knowledge of the bearing and declivity of the strata, in the place where any indications of coal are found, before we can form any judgment of the discovery, and know how to make a proper use of it.

When a seam of coal runs parallel to a glen or gully, and crops out any where within the banks upon one side or the other, there is a great chance of discovering some indications of the coal, perhaps in several places as you advance up or down the glen.

I have shown already, that the outburst, or superficial vestigia of a stratum of coal, upon a slope, is always found to slide downwards, and that the longer and more precipitate the slope is, the farther down the vestige will slide when the crop of the seam happens to be high up. I have also shown, that the extremity of the vestige of a coal seam at the surface is sometimes dissolved into a soft sooty substance, hardly distinguishable from a thin stratum of black clay or earth; however, the superficies of all coal seams are not so liable to be dissolved to that degree. The debris of

some of the splent and cannel coals frequently remain in hard and sharp masses of various sizes, even when mixt with the soil, and removed at some distance from the solid crop of the seam; and some of the cherry coals, or roch coals, as they are called in Scotland, do not dissolve upon the surface into an undistinguishable mass like a friable clay; but, on the contrary, although the debris, or coal rubbish, at the surface should be broken very small, yet there will be found some sharp angular grains and bits of coal, of the size of pease, nuts, and plumbs. In places where seams of coal crop out, some appearance of the coal will be seen by an observing skilful eye in such glens as we have been speaking of. Sometimes masses of splent or parrot, (*i. e.* cannel coal), larger than a man's fist, will be found upon the side or at the bottom of a ravine, which have slipt down by degrees from the crop of a seam of coal situated above, and sometimes smaller bits like the thumb, or less; but when the seam happens to be a cherry coal, the debris or vestige of the coal which has slipt down, is then a great deal smaller, very often like dust, and part of it in small distinguishable grains, though perhaps no bigger than pease.

From these enquiries it appears, that the vestigia and appearances of the outburst or crops of
different

different seams of coal are of three sorts; 1st, Pretty large masses of hard coal, not so apt to dissolve when exposed to the influence of the external air: 2^d, Smaller masses and grains of cherry coal of a diced or cubic form, which is frequently mixt with a foot-like coal dust: And, 3^d, Coal dust, without any visible grains and masses, sometimes resembling foot, and sometimes hardly distinguishable from a blackish or dark brown friable earth. One or other of these vestigia or appearances of coal are frequently to be found mixt with the upper soil upon the side or at the bottom of a glen or gully. Sometimes they are to be found appearing under the upper soil upon the face of the rock in some break or scar.

When any of these appearances are discovered within the banks of a ravine or glen, the first thing to be done is to go to a place where the superficies of the strata are to be seen in the same glen, and to examine the points of the compass towards which the strata trend, and incline or dip; and when these points are ascertained, you will be enabled to know whether the strata run parallel to, or cross the glen, where the appearance is found. If the bearing of the strata is either parallel, or nearly parallel to the trending of the sides of the glen, you can easily discover the

the seam of coal, by digging small pits at a proper distance from one another, cutting through the vestigia of coal, and in a line up the slope; and if the last of these, that is, the upmost, should happen to have no vestige of coal, it is very probable that you have overshot the seam, and in that case you must go back to the next pitting in which the appearance of coal was found, and dig a cross cut in a line upwards, and you cannot fail to cut the surface or crop of the seam of coal, if you dig to the face of the rock or solid strata. If the bearing of the strata crosses the glen, either at right angles or in a diagonal direction, your digging then must be directed across the course and bearing of the strata; and perhaps in this case it may be more proper to dig a trench, in a line from the place where the vestige of coal is found, than to make pittings; the trench to run across the bearing of the strata; but of this those who are upon the spot must judge which method of trial is best, as circumstances vary considerably in different places.

But it frequently happens that the superficies of the strata are not to be seen in several places, in many glens the face of the solids being often concealed under a deep or thick cover of gravel sand or clay.

It is very common in a coal country to find banks or beds of small gravel, and likewise beds
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of sand and clay, mixt with small masses of coal of various sizes, which indeed is an indication of your being in a coal country ; but such bits of coal so found are no indication of a seam of coal in this place ; nevertheless, a seam, or seams, of coal may be there, but the bits of coal lodged in the banks of sand or clay are not the vestigia of them, as these masses of coal were carried there when the rest of the sand or clay with which they are blended was lodged there by water ; and, therefore, it is necessary, when you find small masses and grains of coal, to be able to judge whether they are mixt with the natural soil, or in adventitious beds or banks of gravel, sand, or clay. If amongst adventitious matter, you need not dig, unless you have some other more certain indications of a seam of coal being near.

Of all the beds and banks of adventitious matter which are found above and conceal the superficies of the solid strata from our view, clay is the most common in coal countries ; though it frequently happens that we have to dig through sand or gravel in sinking coal-pits, yet we more frequently sink through clay ; and of all the species of clay, a strong, hard, and dry clay, mixt with less or more of sand, gravel, or stones, is the most common in coal-fields. When this species of clay is blended with boulders and bullets,
with

with some gravel and sand, it is frequently very strong and dry, and almost as hard as a rock.— In some places this species of compounded cover clay contains specimens of all the strata found in the neighbourhood; and when it is of this sort, which may be called a general composition, it is frequently a very curious and a very confused mass of indigested matter. Grains, masses, and fragments of every species, quality, and colour of the strata to be found in that country, are promiscuously blended in this heterogeneous species of clay.

I have in the third part of this work investigated and explained the natural history of these compound clays, and of the beds and hillocks of sand and gravel found in so many places upon the surface of the earth, and, therefore, I will not lose time here in repeating what I have said elsewhere.

There are in some places vast beds and banks of these compounded clays, which cover and effectually conceal the superficies of the strata for a considerable extent; sometimes over the whole face of an extensive neighbourhood, excepting where it happens to be cut through by a strong current of water; but it is sometimes so hard that the strongest currents are not able to wear it through. I have in many places seen this species
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of clay from a yard up to thirty or forty yards deep, and more, above the rock or superficies of the strata; and, as I hinted above, it frequently contains specimens of the coals, and of other strata found in the neighbourhood. I have often seen such a quantity of larger and smaller masses of coal blended in this sort of clay in some particular places, as might deceive many, and make them imagine that it was the vestigia of the crop of a seam of coal. I know that many do imagine it, and I have no doubt that several will be induced, from the quantity and variety of bits of coal found in different places in this clay, to make some trial in it; and for such as are not very well acquainted with this composition, perhaps it would be wrong to dissuade them altogether from digging a little in it, because it is in some instances pretty difficult to distinguish between the vestige of the crop of a seam of coal, and a nest of bits and grains of coal blended in the compound clay; especially when we consider and know that a real outburst of the crop of a coal is frequently mixt with clay at the surface of the ground; and, therefore, when appearances are so doubtful that a gentleman cannot readily distinguish with certainty whether the masses and grains of coal which he beholds are the vestigia of a seam or adventitious, it may be proper for him to dig a little. If the appearance of coal, upon

upon which he is going to make some little trial, is adventitious, and belonging to the compound clays, the symptoms will not alter much upon digging in it, there being sometimes a great depth of this clay above the superficies of the solid strata, and, therefore, he will not find any material change in digging. He will find no appearance of any discovery; there is nothing but the same compounded clay continuing with adventitious grains and masses of coal in it; which coal is part of the composition, and the whole mass of the clay, as well as the coal, is adventitious.

I hinted before, that it is the character of some beds of this clay to be compounded of specimens of all the neighbouring strata; and in fact these specimens, and the whole of this composition, was torn off the superficies of the strata by water, soon after they were formed, before induration was complete; and the matter so torn off was carried forward a little by the weight and force of those high tides; and when the tides began to abate, and fall lower and weaker, these beds of clay were left as we find them when the weight and force of the water failed.

The numerous hillocks and extensive beds of gravel which we behold in so many places upon the face of the earth, have the same origin.—Those gravel beds and banks are also a composition of various species of such strata as were indurated,

durated, and they were likewise torn off the rocks, and after being rolled in the waters until all the asperities and sharp angles were worn off, the whole was lodged as we find it.

As several of these beds of compound clay contain specimens of all the strata of the neighbourhood, which is an evident fact, easily proved by comparing the specimens with the strata from which they were broken off; and as coal is a part of this composition, I give this as another symptom or indication of coal, which may be called an infallible one. I cannot, it is true, by seeing this symptom of coal, pretend to say there is a seam of coal within so many yards, nor within so many hundred yards: I have nevertheless no difficulty to assert that there is coal in the neighbourhood where this compounded clay appears with masses and grains of coal in the composition.

I have been thus explicit in pointing out the difference between small masses of coal discovered in the compound clay, and the real vestigia of the crop of a seam of coal, for the information of such as cannot yet perfectly distinguish the one from the other.

After this explanation of the origin, appearance, and component parts of these beds of cover clay which so frequently conceal the superficies

of the strata from our view, I hope that all gentlemen, even such as are not adepts in this science, will be able to distinguish between small masses or bits of coal found in these beds of clay, and such as belong to the real outburst or crop of a seam of coal; and in cases where they are not certain at first, and resolve to dig, they will soon be able to distinguish between the vestige of the crop of a seam, which is generally continued, and increases from the first discovery until we find the crop of the seam betwixt roof and pavement; whereas the bits found blended in the compound clay are generally detached from one another, are imbedded in a vast mass of clay, without any continued stratum or vestigia which might lead to a seam of coal; and, therefore, when gentlemen are satisfied that they are digging in a bed of this species of clay, it will be needless for them to proceed, there being no hopes of making any discovery in it.

There is one circumstance yet to be remarked. The masses and bits found in the compound clay are generally hard, clear, and perfect; whereas the bits found in the vestigia of the crop of a seam of coal have frequently a decayed imperfect appearance, sometimes quite discomposed or dissolved into dust, resembling soot or black earth; and where there are small masses of coal, they
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are generally tender and friable, and blended with different quantities of dissolved coal dust, excepting in the case of the seam of coal containing a stratum of hard parrot or of hard splent, as these sometimes produce pretty large masses, which are found slid down the slope, or scattered about the surface, at a considerable distance from the crop of the seam of coal. These larger masses frequently appear in considerable degrees of perfection, without any other vestige of coal, at a distance from the seam, though other vestigia may be found nearer to it. Masses of cannel and hard splent coals bear tumbling about, and they bear the external influence and changes of the air without injury as well as some stones; but all the cherry coals, roch coals, and some of the splents, discompose at the surface, and fall either to dust or to small grains, and it frequently happens that some parts of the same stratum of coal dissolves to powder, and other parts of it fall down to small debris, or to grains and bits of various sizes; and these are found blended together either upon the surface of the ground or under the cover clay, or other matter.

I observed before that the vestigia or appearance of coal is sometimes so near the surface as to be discovered by the spade and by the plough; and I have frequently seen small bits or grains of coal mixt with the mold cast up by the mole,
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when the superficies of the strata happened to rise to the surface of the ground; but when bits or grains of coal are cast up by the plough or by the mole, it should be considered and judged whether such grains of coal are adventitious, or belong to the vestige and crop of a seam.

Coal has been laid down in a vast number of places upon the face of the earth for burning lime and bricks, and for many other purposes, and a quantity of the small debris of it will remain; and, moreover, where coal is burnt for common fuel, a quantity of the debris of it is carried out with the ashes and spread over the fields. In these cases, bits and grains of adventitious coal will appear after the plough, and in the mole hillocks, where no seam is to be found, which circumstance ought to be well considered before gentlemen are too sanguine in their expectations.

I have already advised gentlemen to examine well the glens and rivulets, and all other places where the superficies of the strata may be seen, which are likely places for discovering strata of coal.

It generally happens in all coal fields or coal countries, that the superficies or outburst of a great number of seams of coal are to be seen in such places, which I know for certain from my
own

own observation and experience; but of all the places where coals are discovered, new made ditches are the most remarkable; however, it must be noted, that no mineral discoveries of any kind can be made in ditches, by forming roads, nor by any other superficial methods of digging, where a thick bed of clay or a bed of gravel or sand covers the superficies of the strata, but where the rock or strata come up so high as to be found immediately below the upper soil, or under a very thin bed of surface clay, the vestigia of coal are frequently thrown up by ditching. I have very often seen three or four, or half a dozen crops or vestigia of seams of coal appearing in the ditches which were newly made to enclose a field of ground.

I need not observe here that the symptoms or indications of coal appear in ditches by black strokes across the dyke or bank thrown up out of the ditch, which strokes or stripes are sometimes discernible at a considerable distance.

When ditches are cut across the crop of a seam of coal, they throw up a quantity of black matter upon the top of the dyke, which generally appears obvious; but the vestigia of coal so thrown up is not always distinguishable at first sight from the vestigia or crop of blaes, and all the black coal tills. The one is generally as
black

black as the other to appearance, and, therefore, circumstances must be well examined.

If a quantity of black argillaceous matter is dug through and thrown up, without any bits or grains of coal appearing in it upon examination, then it may be concluded that you have only cut through blaes or some species of black coal till ; but if any bits or grains of coal are found, some trial should be made by digging.

I hinted before, that the extremity of the vestigia of a seam of coal is sometimes no better in appearance than an inch or two of black clay or earth. When such a faint and obscure appearance is found in cutting ditches, it should be narrowly inspected, to see if any symptoms of coal can be found in it, such as small grains of coal, or if it be of a friable quality and appearance, like wet coal dust. In this doubtful case you should dig a little in it, following the vestige towards the acclivity, if the ground is sloping, but if it is a perfect plane, towards the strongest side of the vestige ; and if a seam of coal crops out there, and if you are digging towards it, the vestigia of the coal will encrease, and grow more and more like coal as you advance towards the seam, and grains of coal will appear, which will encourage you to go on with your trial.

But the vestigia of coal discovered in cutting ditches are not always so obscure. It is very common

mon for a quantity of coal to be thrown up with the spade, which may be seen in grains and small masses upon the top of the dyke, especially after a shower of rain ; and it sometimes happens that the crop of the coal is so near the surface of the ground, that they cut through the real superficies of the seam in the ditch, and throw up the small coal with the spade in great abundance.

When the vestigia of a seam of coal is once discovered in a ditch, or in any other place or situation, it may be proper to make such trials upon it, by pitting towards the dip, or by following the vestigia with a trench, as will trace the seam under cover in solid metals, or until the proprietor is satisfied. No true judgment can be formed of the thickness and quality of a stratum of coal, until it is found under the cover of solid metals, that is, until you have it within the solid strata, and between roof and pavement. When you have pursued the vestige of a coal until you have it within the solid strata, with a solid regular roof above the coal, and a solid and regular pavement below it, you can then judge of its thickness, as it seldom alters much in thickness when you go farther down in it, and you can sometimes judge of its quality. When you have a regular roof and pavement, you can judge of some of the characteristic qualities of your coal ; you can then see whether it is clean or foul coal,
that

that is, whether the coal is pure, and free of heterogeneous matter, or if it is mixt and blended with pyrites, stone, or argillaceous matter ; or if there are beds of stone, blaes, &c. running in the middle of the seam of coal, and so dividing it into two or more strata : and sometimes you can judge pretty near the crop or surface whether it will be a hard or soft coal, and if it will prove a good burning coal or not ; though you cannot always judge of these last mentioned qualities so near the surface, as some coals, which appear soft, tender and useless, when but a few fathoms below the surface, improve wonderfully in strength and quality at a greater depth, when under a great weight of super-incumbent strata. Some seams of coal appear and burn pretty well when first found between roof and pavement, and others are good for nothing so near the surface, and not fit for use until they are under many fathoms of solid cover. This is very well known in experience, and generally the deeper down the better.

Of all branches of business ; of all the experiments that a man of sensibility can be employed in or attend to, there is perhaps none so amusing, so engaging, and delightful, as a successful trial upon the vestigia or appearance of a seam of coal, or other mineral discoveries.

When you are attending the people who are digging down or forward upon the vestige of the coal,

coal, and that the indications are increafing and ftill growing better under your eye, the fpirit of curiofity and attention is awakened, and all the powers of expectation are elevated in pleasing hopes of fuccefs; and when your wifhes are crowned with fuccefs, when you have difcovered a good coal of fufficient thicknefs, and that all circumftances are favourable, the heart then triumphs in the accomplifhment of its wifhes with folid and fatisfactory joy. There is more rational delight, more fubftantial pleafure and happinefs, to be enjoyed in fuch fcenes as this, than in all the celebrated amufements which luxury invents and purfues.

I imagine and hope that I have been fo explicit in pointing out the appearances of coal upon the furface of the ground, and of the method of improving fuch appearances, that any gentleman who difcovers fuch appearances in his eftate, will be able, with his own fervants or labourers, to make fuch trials as will fatisfy him as to the exiftence of a feam of coal, and of what thicknefs it is; and it will enable him to guefs its quality, without fending for men of fkill in this firft experiment.

In my account of the external appearances and indications of coal, I have faid nothing about the Petroleum and Ochre, which are faid to iffue out

from coal, about which a great coil is made by many who imagine that they understand these matters; and I have purposely avoided saying any thing about them as indications of coal, for a very good reason, viz. because I would not wish to deceive. These at best are but vague and uncertain symptoms of coal, and in most places where they abound, they are no symptoms at all.

The petroleum is an oily inflammable substance, found upon the surface of the earth, which in many places issues out of the rocks, from peat bogs, and from putrified vegetables, in a thousand places where coal is not to be found; and ochre is composed of earthy ferruginous particles, carried by water from mineral bodies, and lodged or left by the water in various situations and quantities, and both of them frequently a hundred miles from coal. Why then should we attend to, or have any thing to do with symptoms so very uncertain as these? Some species of petroleum may have a near relation to coal, and under certain circumstances, for any thing I know to the contrary, coal may produce some little of it, but I am confident that it does not produce ochre. The petroleum is not only to be found upon the surface, but also it appears to me to be an universal oil, present in lesser or greater quantity, and under some form or other, in all fossil bodies, and so plentifully diffused in the atmosphere, and
through

through all the soils, as to be one of the chief principles and component parts of all plants. It is evidently combined with, or infused in several rocks and strata, which compose the superficies of the globe. Many of the coal blaes, and of the thin slate-formed argillaceous strata of the coal metals, contain it in such quantity as to produce a strong flame when put in the fire; and some of them, when fire is applied to the side of a large parcel, will burn throughout of themselves without the assistance of any other fuel; as, for instance, at Pitfirran in Fife, where several large heaps have been burnt, and where the whole mass or heap grows red hot throughout; but the fire neither consumes any of the quantity or bulk, nor does it produce any ashes; and after the fire goes out of itself, the blaes assume a pale red colour, and are so much harder than before as to make good materials for private roads. Petroleum is likewise well known to be diffused in lesser or greater quantities through the body of all lime-stone; and it is often found lodged in its cavities, sometimes of the colour and consistence of basilicum ointment of the apothecaries, which I have seen at the Camp lime-quarries and at Dechmont lime-quarry, the one to the east, and the other to the west of Mid-Calder in Scotland.

I have frequently seen thinly stratified limestone near a hundred miles from coal or coal metals, containing so great a quantity of this natural oil, as to produce a strong flame when put in the fire, and the oil could be seen oozing out in the fire, though the stone was hard, and made a good produce of excellent lime when burnt for that purpose. I have also seen many black, shivery, and slate-formed or laminated strata of the mountain schistus, that is, such as are every way foreign from, and situated at a great distance from the coal metals, produce nevertheless a strong flame in the fire; and I have seen, very far from coal, beds of black hard stoney matter breaking or naturally separating into small angular masses, so plentifully impregnated with this oil as to emit a strong flame when put in the fire.

Now, from all these observations and facts, and many more which might be produced, it is abundantly evident that this fossile oil is universally diffused through all substances within the superficies of our globe, and upon the surface of the earth, and is perhaps a constituent part in the composition of almost all bodies, though in widely different degrees, combinations, and forms.

I am aware that some will grant me that the petroleum or natural oil is found in many fossile bodies, upon the face of the earth, yet, nevertheless, that coal is the chief repository of it.

Many

Many gentlemen are of opinion, that the flowing of the petroleum is the principal, if not the sole original cause, or the producer and nourisher of coal; and these gentlemen argue thus, and say, "That the hypothesis appears highly probable, as it is a well known fact that different coals are better and worse in various degrees; some of them being very good, some indifferent good, and others worse, very bad, and imperfect.— May we not suppose, say they, that all these have arrived at different degrees of maturity; that the worst are yet far from being ripe; but that they will all come to perfection in the course of a very long time?"

This theory, which makes coal to be now a progressive work of nature, may appear to some plausible; it is, however, very liable to weighty objections.

A seam of coal is an original stratum, which keeps its station as regularly as any of those placed above and below it. Of this truth I have shewn abundance of instances, to which I refer.

Now, if a seam of coal is an original stratum, the matter of it must have been collected, and the stratum of coal formed when the superincumbent strata and those below it were formed. This is necessary in the nature of things, because new strata cannot now be inserted among the original strata.

This

This account of the matter will not agree with the supposed progressive formation, and yet this is a well known fact, obvious to the most common observation; and, moreover, the impurities of bad coals, that is, the heterogeneous matter found blended in the different seams of bad coal, are real fossile and mineral substances, such as pyrites, iron-stone, free-stone, and several sorts of argillaceous matter, which will keep their stations where they are; and, of consequence, such coals as contain these heterogeneous substances, must for ever remain as imperfect as they now are; and, therefore, we must give the coal a more ancient date in the annals of natural history; and we must also allow it another origin, or natural immediate cause, though the petroleum, for any thing I know, may in part be the remote origin of it.

Coal has very obvious and striking appearances of being composed of vegetable substances. I have frequently seen evidently the grain and other characters of wood in several coals; and in some enquiries and disquisitions in another place, viz. in my natural history of the strata and rocks in general which compose the structure of the superficies of our globe, I have made it evidently appear, even to a demonstration, that the antediluvian timber was the original of coal.

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It will appear highly probable, from what is said in that history, that the greatest part of the antediluvian earth was covered with a tall and luxuriant growth of timber, and it is easy to conceive that so many millions of acres of tall timber formed into coal, would produce a very great quantity of that valuable fossil; and in this respect the effect and the cause exactly correspond to one another; the quantity and variety of coals found within the superficies of the earth, seems to tally with the immense quantity of timber which produced it. I am not the only person who has seen and observed the appearance and characters of timber in coal. Several other gentlemen who are conversant in these matters, have assured me, that they have not only frequently seen evident marks and indications of the grain of timber in coal, but that they have also seen considerable pieces of whole timber, which, though black as coal, yet not so dissolved and altered as to lose the original form and grain of a round piece of timber.

From every situation and circumstance relating to the strata of coal, and of the other several strata which accompany coal, it is abundantly evident that they were all formed by the agency of water, as well as the rest of the superficies of our globe; which subject I have clearly explained in another place; and, therefore, it follows, by a natural and necessary inference, that the strata
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of coal, and of all the coal field, were formed at the same time as the other superficies of the globe, though this time comprehended the continuation of days, weeks, and months; and it appears to me that the strata of coal and of the coal field were among the last that were formed; which circumstance I hinted at before.

All the beds or seams of coal are equally well stratified with the other concomitant strata of the coal field, and the strata of coal are in every respect fully as regular as any other species of strata found above or below the coal; which subject I have also explained above; and besides these general characters of stratification which seams of coal have in common with the other strata of the field, a great many seams of coal exhibit, moreover, such internal marks and characters of stratification, as clearly point them out to the cursory observer to have been formed by the motion or flowing of water.

It is very common to see the constructure of many seams of coal composed throughout of a great number of thin and very regular layers or strata of coal, which seams of coal in appearance, and in reality, are of a laminated structure. Some of these laminated seams of coal are composed of a great number of thin strata of nearly the same quality and texture, and other seams contain strata or lamina of two or three different species
of

of coal. And again, some of them contain a considerable number of species and varieties of coal in the same individual seam or stratum; and these several varieties of coal of different appearance, quality, and texture, are all disposed in very regular strata or laminæ, lying one above another in the same stratum of coal. We commonly find in one seam of coal a stratum of splent and a stratum of cherry coal, and sometimes we find strata of splent, cherry coal, roch coal, parrot, and of run splent in the same seam. There is a thick stratum of coal among the edge seams of Gilmerton, Loanhead, &c. in Mid-Lothian, called the Great Seam, which contains coals of several different qualities and varieties, such as splent coal, roch coal, run splent coal, a stratum of fine parrot, or cannel coal, of excellent quality, and a stratum of coarse parrot of inferior quality; and there are in the same great seam varieties of the roch coals and of the run splents; so that this individual stratum contains a considerable number and variety of coals of different appearance, quality, and texture; and this variety of coals is found in the great seam in all the different places where it has been worked, in a distance of several miles in length upon the bearing of the coal.

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Having

Having mentioned many different sorts of coal, it may be proper to give a short history of the several known species of coal in a regular series.

There are at least six different species of pit coal, such as,

1st, Caking coal, of a fat bituminous or resinous quality which melts in the fire, and then runs together into one mass when thoroughly heated, and burns to a cinder with a thick fuliginous smoke; but the best varieties of it produce very little ashes.

This species of coal is commonly of a fine black clear colour, of considerable brightness when newly worked, and remarkably clean and pure, though not without exceptions, being in some places debased with clay, pyrites, and other foul admixtures.

There are several varieties of this species of coal. One of them is called cherry coal, which is of a cubical or diced structure, the most tender and brittle of all coals, which generally breaks small in working and carriage, but the smallest coal dust of it cakes or runs together in the fire to a strong and pretty hard cinder when it is thoroughly heated, and even before it is all quite red hot. Some varieties of these fat coals exhibit no regular form or structure, but are run together in the stratum to a general confused mass, with-

out

out any appearance of laminæ or other determinate figures. Some of these are soft and easily worked, and produce mostly small coals, and others of them are more hard, strong, and solid, and yield great coals in working; but none of these are quite so hard as some other species of coal.

Northumberland, and other parts of the north of England, are famous for producing abundance of this species of coal, great quantities of which are shipped at Newcastle and Sunderland, and it is commonly known by the name of Newcastle coal.

This species of coal is not quite so common in Scotland as the north of England. The greatest quantity and best quality as yet discovered in Scotland, is at Balmule, near Dunfermline, in the county of Fife, where the seams or strata of coal are of good thickness; and they will, in the course of time, become of great value, when this species of coal is all worked to a great depth in the north of England. There are several seams at Balmule of excellent quality, which stretch longitudinally through a considerable length of country, especially towards the north-east. There is also pretty good caking coal at Pitfirran, and other places in the neighbourhood of Dunfermline; and in other parts of Scotland,

land, but not in such abundance as in the north of England.

2d, The second species I shall take notice of is called rough, roch, or rock coal, which is a free coal of various degrees of strength and hardness, commonly of a good black colour, though not so bright and glossy as the Newcastle coal.

Most of the varieties of this species burn to a good cinder, though they do not cake, run together, nor cohere in the fire ; but they frequently produce more ashes than the Newcastle coal, though not all of them. Some of the varieties of the roch coals are as pure and as free of heterogeneous mixtures as any coal whatsoever ; and these pure roch coals produce very little ashes, and are in fact the best of all coals for culinary uses, making a strong, clear, and open fire.

There are many varieties of the roch coals. Some of them are finely stratified, the seam of coal appearing to be composed of numbers of thin and regular strata or beds, lying one above another, and strongly cemented together, and broken transversely into irregular square masses of no determinate size or figure.

Some varieties of these coals approach to a cubical or diced form, which are called cherry coals, although they want the caking quality.

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These are generally soft, brittle, and easily worked, and break small in working and carriage. Some of the rock coals are run together into a hard strong mass, which appears of a flat or horizontal texture, but without any distinct strata or laminæ in the coal wall or stratum.

In short, the form and texture of the varieties of the rock coals are so numerous, that it would be tedious to enumerate them all. Many of these coals are very hard and strong, producing large masses or great coals in working, which stand carriage well. Such of these coals as do not burn to a good cinder are debased by a considerable proportion of some earthy matter, which causes them to produce a great quantity of ashes, and this great proportion of ashes prevents or spoils the cinders.

Great abundance of this species of coal is found in the counties of Edinburgh, Linlithgow, Fife, Stirling, Lanark, and other parts of Scotland, and likewise in Shropshire and several other parts of England.

3d, Stone coal, or splent coal, which is of a laminated or slaty structure, burning freely with a strong flame and much smoke, and producing less or more ashes in proportion to the purity or debased quality of the coal.

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This species of coal is remarkably hard and strong, and difficult to break across the bed of the strata, excepting at the natural transverse cutters, but it cleaves or splits easily into thin broad flags like boards, which kindle almost as readily and burn as freely as fir dales. No fossile bodies of considerable bulk are more regularly stratified than splent coals. Some varieties of this species are very light and pure, from which a natural oil sometimes oozes out in the fire, and these burn fiercely with much flame and smoke, but they produce very little ashes. Some of these burn with such a clear strong flame as to give a light equal to that of a number of candles; and the country people in many places use no other light in the winter nights. Other varieties of it are more stony, hard, and ponderous, which produce much ashes, and some of them are so foul as to leave a white stony mass in the fire, which will not burn down to ashes.

One variety of this coal is by Scots colliers very properly called *run splent*. This variety is of a more clear and glossy black colour than most of this species, which is of a more dusky black than most of the other coals.

Many of the run splents exhibit a mixed texture, being partly laminated and partly uniform, like broken pitch, and some of them are laminat-

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ed throughout the whole stratum; but they all appear to be of a mixed quality, and the strata or laminae are so run and cemented together, that they will not split asunder so easily nor so completely as the perfect splents.

All the run splents are certainly of a mixed quality, some of them being composed of about half and half of the second and third species, and some of them of the same proportions of the first and third; and, as a proof of this mixture, the last partakes of the caking quality of the first species in so considerable a degree as to run together in the fire, and to produce excellent cinders in burning, whereas the pure splents burn to ashes.

All the run splents are amongst the best coals in the world for culinary and all domestic uses. The splent or stone coals are very common in the Lothians, Fife, Ayrshire, and all the other coal countries of Scotland, and in some parts of England.

4th, Cannel coal, or parrot coal, which is of a good black colour, and of a fine, smooth, solid, uniform texture, considerably hard, and breaking in any direction. When this species of coal is clean and free of heterogeneous mixtures, it is pretty light, makes a chearful fire, with a strong flame

flame and but little smoke; and it burns to a less or greater quantity of ashes in proportion to the good or bad quality of the coal.

Some of the best varieties of this coal are so fine and solid as to be often turned and otherwise formed into many sorts of utensils and trinkets, which bear a good polish—but they are more beautiful than durable; however, the coal is so fine and clean as not in the least to stain the hands nor the cloaths when made into toys.

This species of coal is very common in the county of Edinburgh, and in many other parts of Scotland and England.

5th, Culm, or blind coal, which is of a fine clear, glossy, black colour, and of a bright metallic appearance.

This is a very singular species of coal, which emits neither smoke nor flame in burning. It is not very easily kindled, but when thoroughly ignited, it burns a long time with a clear, strong, glowing heat, like charcoal, being very durable, and without the least smoke or flame from the best varieties of it; but it emits a strong, disagreeable, suffocating effluvia when burning.

This coal is very free and tender, and generally breaks small in working and carriage; but it has nothing of the caking quality, nor does it

it burn to a cake or cinder, nor produce much ashes.

It is very remarkable, that when a quantity of culm has been all on fire in a grate or furnace, and after every particle of it has been burning with a clear glowing heat, when the fire is either extinguished or allowed to go out of itself, what little culm remains in the grate or furnace has no marks of fire on it. Even the surfaces of the small bits which remain unconsumed, retain the same glossy black colour, the same texture and bright appearance as before, and partly of some other species of flaming coals.

6th, Jet, which is a peculiar species of coal, is of a fine bright black colour, remarkably clean and light, of a smooth and solid texture, and bearing an elegant polish; and, therefore, much used in making snuff-boxes and other trinkets.

Jet has a near resemblance of the finer varieties of cannel coal, excepting that the cannel coal has an uniform texture, without any visible grain, and breaks in any direction with equal ease; whereas jet has the apparent grain and structure of wood, not readily breaking across, but it cleaves easily lengthways like the splent coals.

Jet is found in England, and in other parts of the world, in detached separate masses of various sizes lodged in other strata, and likewise in clay

pits and in other loose matter, lying above the superficies of the solid strata; but as I do not know of any regular strata of jet being as yet discovered any where, it cannot properly be included in a natural history of the strata of coal.

However, the natural history of jet leads me to imagine that there are strata of it within the solid superficies of the globe, although they are not yet discovered. Samples of all the other species of coal are also found in detached masses of various sizes, lodged in the strata of free-stone and others, within the bounds of the coal fields or coal countries, and likeways in the beds and banks of clay, sand, and gravel; sometimes in such considerable quantity as to deceive many, who are led to imagine, from the abundance of this loose coal which they see, that they have discovered the crop or surface of a stratum of coal; whereas it is only a great quantity of detached masses and particles of coal blended in such clay, sand, and gravel as lies above the superficies of the solid strata. But it is a certain fact that these samples of coal which are so found in detached masses and particles lodged in the strata, and in the banks of clay, sand, and gravel in coal countries, are exactly of the same species, texture, and quality as the strata of coal which are found in the same neighbourhood as this loose coal; and, moreover, this loose scattered coal
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is only found in the neighbourhood of coal, or never far from the coal fields ; which fact I have thoroughly investigated and explained above.

From this known truth in the natural history of coal, which many have, and every body may observe, I am led to imagine that there may be regular strata of jet as well as of the other fossile coals : Samples of all which are found in like situations and circumstances as the jet, and no doubt they have the same origin, which I have shewn above to be the superficies of the regular strata of coal.

This account of the several species of fossile coal which have been discovered hitherto, makes it evident, I might say to a demonstration, that coal is composed of vegetable substances, and that the antediluvian woods is the real origin of it.

The form, grain, and texture of timber has been so repeatedly seen and observed by naturalists, and by other men of judgment and skill, in such great quantities, and in so many places, that the position cannot be denied without rejecting the evidence of the phenomena of nature.

That wood is the origin of coal is so plain and evident a truth, that we can almost trace and point out the particular species of wood which composed

composed particular species of coal; such as, for instance, we may suppose, that the long-grained resinous pines and fir timber are the principal ingredients in the composition of our fine flaming splent coal, which, like the fir timber, will readily cleave from end to end, and will kindle almost as easily and burn as freely as the resinous fir timber itself. The like comparative characters and similitude might be found and pointed out between other kinds of wood and the other species of coal, which would be found to correspond with remarkable exactness, after allowing for the various mixtures of several sorts of wood in one stratum of coal, and for the great alteration the wood must suffer by being so long agitated in the waters of the deluge, and the great effects which composition and mineralization must necessarily have upon the appearance and properties of the several species of coal.

Some of our coals indeed are remarkably clean and pure for such bulky fossils placed among numerous strata of heterogeneous substances.—These discover very little of foreign matter in the composition of the stratum; but, on the other hand, many of them are blended and mineralized with various proportions of stone, clay, pyrites, and other heterogeneous matter, which debases and spoils the coals to such a degree that many seams are of an inferior quality, and some
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of them are rendered entirely useless. But as this enquiry and investigation must be conjectural, and would be merely curious, as it could convey no useful information, I will proceed no farther in it.

Coal tar, which has of late been extracted in such great quantity from this valuable fossile, is another proof that wood is the origin of coal.—The coal tar is so nearly of the same nature and quality as the foreign vegetable tar, that there seems to be no other difference between them than what must necessarily be communicated or acquired by the compounded mineralized state of the fossile coal: But I could wish that this proof of the vegetable origin of coal had never been produced. The discovery of coal tar will be of infinite detriment to the nation in the course of time.

The avidity for present profit will prompt many to consume the coal in making tar, which our cities, our populous countries, and our manufactories will soon want. Where iron works are carried on near the tar kilns, I would approve of making coal tar, because, in that case, the cakes produced by the kilns are used in a valuable manufacture, which is a national benefit; but where the tar and iron works are not conjoined, at least in the neighbourhood, the coal tar is a pernicious manufacture.

Let

Let us now return to our enquiries about the petroleum and ochre. If all our coals were found in the concavities of mineral veins, and not in regular strata, there would be some more reason to suppose that coal was produced by the continual flowing of the petroleum or of fossile oil; but where it really is found in regular strata, there is not the least foundation for such a supposition. It is not even possible in the nature of things. I have seen coal in the cavities of mineral veins at Castle Leod, in the highlands of Scotland. This extraordinary coal is lodged in common rake veins, or perpendicular mineral fissures in the mountain rocks, far from any strata of coal, or of the coal metals. The veins at Castle Leod open into bellies or concavities of different lengths and capacity, and close again, or check, by the sides of the veins coming together; and they have every character and description common to good rake veins, and the coal is lodged in the cavities of them, exactly in the same manner as lead, copper, &c. are found in such veins in other places. I got some coal dug out of one of these veins, which I burnt in the house: The coal was very soft and tender, being very near the surface; but it was perfectly clean and bright—about one foot thick where I opened the ground, but it grew thinner towards the ends of the belly or concavity of the vein,

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and it soon dwindled away to nothing, and twitched out entirely; and I saw it open again in several places in the bearing of the vein. This coal was exceedingly fat, so as to run together strongly in the fire like the best of the Newcastle coal. I look upon this phenomenon in the natural history of the mineral kingdom as a great curiosity. I call it a phenomenon, because it is an extraordinary appearance quite out of common experience. I did not know any thing about coal in such a situation and circumstances until I saw this. I had never heard nor imagined any such thing until this offered itself to my consideration. I was at all due pains to investigate this phenomenon thoroughly, so as not to leave out any circumstance which should be considered, and so as not to be mistaken in any point.

There are several mineral veins at Castle Leod running parallel to one another upon the north-east side of a pretty high and rocky mountain; and there are some lesser strings branching out from the principal veins.

There is coal found in three or four of these veins, part of which had been wrought out of several bellies of those veins, as far as they could go down for water, before I was there; and as I had no apparatus for drawing the water out of the old works, I was obliged to open new ground farther

farther forward upon the bearing of one of the veins, out of which coal had been wrought.— When I opened the ground the coal was only about one foot thick, and it only continued for a few yards in length at that thickness, before it began to dwindle away by degrees, and it was soon squeezed out entirely at both ends of this little belly; however, I saw evidently, that some of the bellies or concavities of the veins, out of which they had formerly dug some coal, were wider than the one which I opened. Some of them were up to three or four feet wide between the sides of the veins; and the concavities, out of which they had dug coal, were also somewhat longer than the one I opened. But they had chosen the best places for their trials, which was not difficult, as the coal was to be seen in the veins at the surface of the ground. I saw coal in several places in the checks or twitches of those veins between the open bellies, not above one inch in thickness.

The circumstance of these coal veins opening into bellies, or concavities, between the sides, and twitching again by the two sides coming close together, is common to all mineral veins of this description, though the concavities of the veins at Castle Leod are remarkably short; and the twitches, or close parts, are also short, these being a species of piped rake veins; the character
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and description of which is, that they open and close again at short distances in the line of bearing, and the pipes or concavities put down in the dip of the vein parallel to one another.

The coal at Castle Leod will not pay for working, unless it was for some very particular purpose, and that other coal could not be had without an extravagant price; but it would be a noble experiment to put down to a great depth in one of these pipes or bellies of coal, in hopes of finding some mineral ore. There is at least a probability that the coal may be cut out below, and some one of the precious or useful metals come in instead of it.

A change of the produce of mineral veins at different depths is not out of nature and experience. One of the richest mines of Saxony was at first next the surface an iron mine. At some considerable depth the iron was cut out below by copper. It was wrought a long time as a copper mine, but at a still greater depth the copper was cut out below by cobalt; and when they had wrought some time longer and deeper down, the cobalt was last of all cut out below by silver ore, and they have for a long time been working it as a rich silver mine. They have found a change of metallic ores in Germany, besides that in Saxony. I do not pretend to infer from those instances of the German mines, that there is any

certainty ; but there is a probability that some valuable metallic ore would cut out the coal at a good depth in the Castle Leod veins.

I have seen a very small quantity of coal in some other parts of the Highlands, in small fissures of the rocks, since I saw the above ; but none to be compared for quantity to that at Castle Leod.

I saw none above two or three inches thick in any other place, nor of any continuity to signify.

There is coal in the Isle of Mull of a pretty good thickness. I have been told that it is above three feet thick ; and from the imperfect descriptions which I could obtain, I suspect it to be a vein of coal ; but this I cannot positively assert, as I never was there, nor did I ever meet with a person that had been there who had science enough to distinguish between a stratum of coal and a vein of coal, or that could distinguish a stratum from a vein of any sort.

I was a good deal surprized when I first saw the coal veins at Castle Leod ; however, upon weighing the matter, and examining all circumstances, I was afterwards able to comprehend this phenomenon. I have in another place made it evident, that water was the agent in the formation of the strata ; that all the phenomena which we behold upon and within the superficies of our globe were produced by water, and it was

water

water that brought and poured the ingredients of all the mineral ores into the cavities of the veins, while those ingredients were in a fluid state, and consequently it was water that carried and poured the fluid substance of the coal into the veins at Castle Leod.

I have in its proper place fully investigated and explained these subjects in a clear and satisfactory manner, where I have demonstrated that it was water also that spread out the fluid substance of the coal where it is found in regular strata: But I will not meddle with those disquisitions here, which I have fully discussed elsewhere.

I think that I have now made it abundantly evident that coal is not produced by the flux of petroleum, nor by any fictitious cause; but that the strata of coal were formed by water at the same period of time, and in the same manner, as all other strata were formed; and that the origin and source of the coal was the antediluvian timber; and, therefore, it is necessary to give up that point. But it may be said, that I cannot possibly deny, with any shadow of truth, that coal produces ochre, as we have, it may be said, the evidence of our senses for the truth of the position; it being very common to see coals quite red and covered all over with ochre; and upon breaking the masses of coal, it is found lodged in all the interstices, so as to make it internally red

as well as upon the outside ; and it is pretty well known that coal lying dry, without any water about it, for a considerable time before it is wrought, is the cause of this ochry colour, and, therefore, it may appear to many that coal produces ochre, when it is found so plentifully lodged through the whole mass. But, however evident it may seem to many, I cannot grant the position, and therefore it is incumbent on me to refute it. Water is the common vehicle of all fossile particles below ground.

I have asserted above that the fossile oil is very widely diffused, and I now assert that the sources of ferruginous particles or ochre, which are known to be iron pyrites, are perhaps as widely diffused through all fossile bodies.

Iron is found in less or greater quantities almost every where upon the face of the earth and under its surface ; and it is commonly very plentiful, both in balls and strata, in the neighbourhood of coal, and it is very well known that the pyrites are very near, if not altogether as common. Both are frequently found the immediate roof of coal, and pyrites especially is sometimes found in various quantities, and commonly in flattish glebes, mixed in the stratum of coal itself.

Now, as these ferruginous substances are found imbedded in the seam of coal, and very frequently

ly in the roof and pavement of it, no doubt corroding waters find it there, and lodge the minute particles of it in the interstices of the coal seam, where it appears in an ochreous rust when the coal has been laid dry for some time.

That water percolates the pores and fissures of the strata, and carries various particles along in its subterraneous motion, I explained elsewhere. While this subterraneous water is excluded from the effects of the external air, it continues to carry about the various fossile particles which are mixed in it; but when it issues into the external air, or any how approaches it, the quantity of water immediately diminishes by evaporation; and, of consequence, the fossile particles are deserted and lodged where the water left them. When a seam of coal is levelled with an adit, the water is carried off the coal by that drain. The air gets admittance into the works in great quantity through the pits and mines, and then a considerable portion of air penetrates the natural joints or cutters of the coal when it is laid dry, which evaporates the water that was in all the joints or interstices of the seam when it was first drained, and the ochreous particles that were combined or mixed with the water are left behind in such quantity as to colour the coal of a brownish yellow red.

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When water containing ferruginous particles issues out of an artificial adit, or at any natural vent, to the surface of the ground, part of the water is immediately dissolved upon its coming in contact with the external air, and carried up in steam or vapour, and then the remaining part of the water is not sufficiently abundant to carry along all the particles which were at first brought out in it; and, of consequence, some is lodged sediment, and some of it adheres to whatever it comes in contact with, and it continually accumulates, until it becomes a considerable body of ochre. The same happens in a lesser degree in the interstices of the seam of coal, and of several other fossile bodies besides coal. I have frequently seen free-stone and other strata as red with ochre as ever I saw coal, and from the very same cause, viz. the ferruginous particles, first carried, then lodged, and afterwards deserted by the water.

The water which surrounds the strata, and penetrates all their pores and crannies, is plentifully impregnated with iron in a fluid form, or with ochreous particles; but when those strata are drained by an adit or otherwise, the greatest part of the water runs off, and the remaining part is evaporated by the admitted air, and the ochreous particles are left behind, being deserted by the
water

water which sustained them, and they colour all the strata and every fossile body they adhere to. Take a mass of cannel or of splent coal, which is red with ochre, and break it where there is no natural joint or crack, and the heart or solid part of the mass will be found as black as any other coal, and perfectly free from the least tinge of ochre, though the outside and all the joints and interstices should be quite red with it.

I have perhaps said too much about these vague and false symptoms of coal. My apology for so doing is this: I know that many are in danger of being deceived, and that many have been deceived by them. There is much money laid out imprudently in searching for coal upon the sole footing of one or other of these symptoms. I lately saw and examined a remarkable instance of each kind.

In one of these places a number of long mines had been driven into the sides of the hills and glens, and deep pits had been sunk in different places at great expence, upon the faith of the petroleum, because a little of it (a thin film or pellicle) was seen to issue out from some beds of schistus of the mountain rock, and because some of those shivers would flame a little in the fire.

This place is situated in the mountains, at least thirty miles from coal or coal metals, but it
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is not at all uncommon for the schistus, or such platy and shivery rocks to be inflammable, from their being impregnated with the fossile oil.— There is not in this place the least symptom in nature of coal, nor of any strata or species of rock that is found to accompany coal.

In the other instance which I hinted at, they had seen a little ochre, and therefore they certainly must have coal, for coal, said they, produces ochre, and upon this assurance of success they fell to work by sinking and boring to a considerable depth, and at great expence. I viewed this place before they gave over working, and saw nothing round about them but grey indurated strata of the whiny mountain rock,—nothing that had the least affinity or resemblance to any of the concomitants of coal. Upon examining the rubbish thrown out of their shaft, I found that about one third of it was iron ore, mixt with a considerable quantity of iron spar, which appeared to me likewise to contain iron. The mystery of their deception is thus explained: The iron ore produced the ochre which they saw upon the surface, and the ochre led them to sink their shaft upon a vein of iron ore.

Now these two recent instances are in point, and they are both eminent instances of being deceived by such pretended vague appearances.

I have honestly and faithfully endeavoured to distinguish and point out the true and real appearances of coal, and to overlook or reject such as are false or uncertain; and this I have done from the best of motives, viz. to enable such as may be concerned to chuse the one and to reject the other; and, therefore, if I have in any place been a little tedious or prolix, I hope to stand excused, as my intention is good.

END OF PART I.

I have been thinking of you very much lately, and
 wondering how you are getting on. I hope you are
 well and happy. I have been very busy lately, but
 I have managed to find some time to write to you.
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P A R T II.

Of the Natural History of Mineral Veins, and other beds and repositories of the precious and useful Metals.

IN this part we shall treat, *first*, of mineral veins, and of some of the other situations and circumstances of the mineral ores: *Second*, of the most promising and certain appearances and indications of valuable mines; and, *third*, I will point out some few local examples of new mining fields, which deserve to be explored.

There are at least four distinct species of mineral veins, viz.

1st, The *rake vein*, or perpendicular mineral fissure.

2^d, The *pipe vein*.

3^d, The *flat or dilated vein*; and I will venture to add a

4th, Which I will call the *accumulated vein*.

And

And besides these four, which may be called capital veins, there are a great number and variety of inferior strings and branches accompanying the principal veins, and leading to and from them in all directions.

I will attempt to describe the principal veins in the order they are mentioned above, and some of the many branches which are found to accompany them.

1st, The rake vein, called by naturalists the perpendicular mineral fissure, is the most common and best known among practical miners. The rake vein in mining is the same species of perpendicular fissure as was described by the name of slip in the coal metals. They have both the same origin and natural cause, which will be explained in the third part of this work. They are both of them a longitudinal gash, rent, or opening in the rock and strata, commonly running in straight lines. This gash or fissure cuts all the strata and rock quite through from the surface, as far down towards the center as that vein dips, which is generally out of our reach, and as far forward in the line of bearing as that vein reaches. I say the rake vein is a longitudinal gash or fissure commonly in a straight line, which begins at the superficies of the strata, and cuts the rock and strata asunder, generally farther down

down than we can reach. Sometimes this vein stands nearly perpendicular, but it commonly hangs with less or more slope, which slope is called by miners *hading*, or the *bade* of the vein. I said that the rock is cut asunder by this fissure, and the rock upon both sides of the gash is called the sides of the vein, and these sides are called by miners the hanging side and the ledger side, and briefly the hanger and ledger. Some miners call them the hanging side and the hading side, and the longitudinal line which the fissure points to, is called the bearing of the vein.

Of these perpendicular fissures or rake veins, there are two species. The origin of one of these, as I hinted before, is a crack or rent and a slip of the strata, and the other is a gash or chasm in the rock without a slip; the sides of the gash are separated and opened asunder; but the edges of the strata upon both sides of the fracture, continue opposite to one another, so that there is no slip. This distinction or different species of vein is not commonly known among miners or mine-masters, as they are not accustomed to examine all the phenomena of the strata. It is in the collieries that all these things are carefully examined and investigated. The miner is careful to investigate every circumstance relating to his vein, but is very little concerned about the regularity or irregularity of the strata; on the contrary, the
collier

collier is chiefly concerned with the regular strata, and he is only obliged to investigate the veins when they occur to him as slips or gashes, in order to know how to get the better of them.

I will point out some distinguishing marks or characters of each, to enable the miner to know the one from the other when he is working them. The slip veins are seldom wider above than below, but are generally narrower, that is, the sides of the fissures are closer together above at the superficies of the strata than farther down. The slip veins are very subject to checks or twitches, so called by miners, when the two sides, or hanger and ledger, come close together, and no cavity or open space is left between them, so that there is no room for any material quantity of ore to be lodged in a twitch.

There are many of these checks in all this species of rake veins, which continue for several feet or for several fathoms, and the cavities or openings between the several twitches are wider or narrower, longer or shorter, at all possible uncertainty. The sides of many of the veins are very close together above at the superficies of the strata, which, nevertheless, open to considerable but very different degrees of wideness below, and these openings are called the bellies or cavities of the vein; and again, many of them are found regular and uniform, and carry a good rib of ore
for

for a considerable length upon the bearing of the vein, and others may carry some ore and good enough mineral soil in small quantity, and yet never open at all to do any good, so far as we try them. The gash veins, on the contrary, are always wide above, and grow narrower, or the sides come closer together as we work down in them at some uncertain depths, and they often close or check out below altogether. The gash vein is not so subject to twitches in the line of bearing as the slips, but it is frequently crossed and intersected by whin dykes or bars of hard stone, which generally shoves it a little to one side, off the true line of bearing; and I believe it may be asserted of them, that they always carry most ore above pretty near the surface; whereas, on the contrary, the rake or slip veins are generally widest betwixt the sides, and carry most ore below at a considerable depth from the surface.

There is a remarkable mineral vein, of the species I call a *gash*, at Strontian in the Highlands of Scotland. All the rocks in the mining field at Strontian are a grey granite, which is called *moor-stone* by the Cornish miners.

Several veins at Strontian were opened, first by the York Building Company, and a considerable quantity of lead ore was raised by them.

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The principal vein at Strontian is perhaps the strongest mineral vein as yet worked in any part of Britain, in which the York Building Company found a large body of exceeding good ore at first, putting up quite to the day, which they worked out open-cast, that is, their works were cut up quite open to the day, like a large longitudinal trench or gulph, the vein being exceeding wide, and they did not mine it under cover at all. This open-cast has been worked to a great length upon the bearing, and the old works now exhibit a horrid and frightful gulph of great length, and several fathoms wide.

This large vein or chasm in the rock must have happened when the whole mass was humid, before the rock was thoroughly indurated; I say rock, because there is not here the least appearance of regular strata, nor of any stratification at all; the whole mountain being one prodigious mass of grey granite, in which there has been at first a great many cracks or gashes besides this vein, as may be seen by the other mineral veins and the great number of whin dykes seen in this mining field; which dykes cross, intersect, and disturb the mineral veins in many places, and are frequently seen upon the surface; these extensive rocks being mostly all bare, and washed clean by the heavy rains so frequent in that country.

Tradition

Tradition says, that the York Building Company had a rich vein of solid lead ore here, at first of four or five feet wide, quite up at the surface of the ground, besides several feet wide of ore, mixed with spar and vein-stone; and the appearance of the old man, that is, of the old works, seems to confirm the truth of the tradition, the old works being exceeding wide at the surface, and for many fathoms down; and I can see no reason for working so wide, had they not found the ore as wide, the stony parts of the vein where the ore is not so good being sufficiently strong and firm; and, moreover, we do not see any great quantities of waste or rubbish, but such as the washing and dressing of the ore has produced, which is a clear proof that they had some ore, solid or mixed, in all the wideness of the old works, which points it out to have been a very rich vein at first.

The lead ore of Strontian is of the species called *potters ore*. It is a fine rich ore of the kind, very free from any heterogeneous matter of a pernicious quality, but it is at present very much mixed with a fine white and pure spar or fluor, which easily separates from the ore in the ordinary methods of washing, and what remains in the cleaned or dressed ore is found to serve as a flux, and rather furthers than retards the smelting of the ore.

When I was at Strontian a few years ago, they had some ore in several veins, part of which they worked occasionally, now and then, and they had generally about three or four feet of pretty good ore in the soles of the works in the principal vein, flowered and mixed with a pure and friable spar or fluor.

Another famous vein of this species was worked at Llangunog in Wales, in the Duke of Powis's time, whose property it was. Llangunog was perhaps the richest vein of lead ore, for the time it lasted, of any yet discovered in this island. They had there a solid rib for a considerable time, five yards wide, of clean ore in the middle of the vein, which was poured out of the kebbles at the shaft head into the waggons, and carried directly to the smelting house, without being touched by the washers and dressers of ore, besides several feet upon the sides of the vein, which was mixed with spar and other stoney matter, and went through the hands of the washers.

This rich and noble vein was at once cut out below by a bed of black schistus or shiver, and that so entirely, that there was not the least fissure or vestige of the vein remaining, nor ever could be found afterwards, though diligent search was made by the most skilful miners for several years, and at several times.

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Now, I reckon it material for the intelligent mine-master to know the distinguishable difference between the gasb and the slip vein, to enable him to manage properly in the case of such accidents. When the slip vein is in a twitch, whether it be horizontal or perpendicular, the vein will open again when they sink down or drive forward through that twitch; but it never opened, nor no trace of the vein could ever be found at Llangunog, though diligently sought at a very great expence; and no wonder they did not find it, when in fact it was not to be found. The crack or gasb which broke afunder the harder rock above, did not enter into the bed of shiver below, and, of consequence, there was no vein or fissure in the schistus in that place. The cause and natural history of the slips and of the gasbes in the strata and rock, will be fully explained in the third part of this book.

I have selected Strontian and Llangunog as eminent instances of the distinction I made above between the gasb and the slip veins. I have seen a great many more, but I think those two sufficient to explain my meaning, and as a hint to the intelligent miner.

From what has been said of the gasb, it appears, that this species of mineral vein is easily described, it being an open fissure in the rock, generally running in a straight line, often nearly perpendicular,

perpendicular, as that at Strontian, and always wider above than below, at a considerable depth, if we go deep enough to know it.

The other species of rake vein, which I call the slip, is not so easily described, there being a very great variety of veins of that species, and all of them subject to great diversity of accidents. I will point out and endeavour to describe some of the great variety of the rake veins, or perpendicular mineral fissures, which I call slips, and I will begin first with the most regular, and think I may say the most profitable of all mineral veins.

The vein which I call the most regular, is one that runs in a straight line to a considerable distance upon the bearing, sets downwards near the perpendicular, at least it sets down to a considerable depth, with an equal hade or slope, has room enough between the sides, which we will suppose should be at least between three and four feet, or good drift room, and a good regular vein continues so open betwixt the hanger and ledger for a great way forward as we advance upon the line of bearing in it, and for a great depth as we sink or work down in it; or, in other words, the regular vein is equally wide betwixt sides to a considerable distance forward upon the bearing, and downwards. Some of these regular veins are quick and others dead, as they

they are called by miners. A quick vein, or a bearing vein, is one that carries ore, and a dead vein is one that only carries some sort, or sorts, of mineral soil, but no ore. Some of these regular rake veins bear a solid rib of ore, of one, two, or three feet wide, for a considerable stretch forwards and downwards, and some of them bear two, three, or more thin ribs of ore, of various dimensions, from half an inch to five or six inches thick, with spar or other mineral matter interposed between them.

It is a pleasant and chearful sight to see a great number of miners, one before another, in a straight line, working upon stopes, or steps, on a rib of solid ore, of two or three feet thick. I have seen several regular veins, or ribs, of solid lead ore in Wales, between three and four feet thick, and which continued at nearly the same thickness for a considerable time.

One of the most regular and most durable of these was a rib of steel-grained lead ore at Darenfawr in Cardiganshire. I saw at Darenfawr between twenty and thirty miners in a row, one before another, stoping upon the low soles, about fifty fathoms down below the surface, besides as many, or more, who were sumping, driving, and roofing in other parts of the work upon the same vein, and a great many more were at the same time working upon a string which struck
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off with an acute angle from the principal vein; and, as the soles of the string were nearly upon a level with the soles of the vein, I could see the miners who were stoping out the ore in the string, by turning an acute-angled corner where the string came into the vein. This fine rib of ore was generally about three feet wide, both in the vein and string, though in some places it was not above two feet, and in others near four feet wide.

Steel-grained lead ore is generally rich in silver, and this at Darenfawr was remarkably so, the produce in silver being very great.

There are in many parts of Britain, &c. a great many regular veins which carry no ore at all where they are tried, and others of them carry a small rib, or ribs, but so insignificant as not to be worth working, though the ore gave five times the price; and again, others produce small detached bits here and there as we advance in them not worth working.

It is a very common thing to see dead veins, that is, such as bear no ore at all, continue very promising and regular for a great way, both in driving and sinking in them. I have seen more than fifty fathoms driven in some of these regular veins under great cover, that is, under perhaps twenty or more fathoms down from the surface, where the mineral veins were promising,
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and what we reckon likely to produce ore, and yet no ore was found, or none to signify, only so much perhaps as to shew the miners what sort of ore they were to expect, and to tempt them to go on, when, nevertheless, they would continue perfectly regular, and the sides about four or five feet asunder all the way. I will speak hereafter of the mineral soils, hard and soft, which fill up the space between the sides of the dead veins.

There are again many regular veins which are not so wide and roomy between the sides as those I have described above.

I have in the course of my perambulations seen great numbers of perfectly regular veins, not two feet wide, which, nevertheless, would continue fair and regular for a considerable length, which I could easily see when they were washed along the vein by a rivulet, and where the rocks were otherwise made bare.

Some of these regular thin or close veins contain ore at the superficies of the strata, and others contain none at the surface. What they may carry farther down cannot be known without proper trials, and it is but seldom that proper trials are made in them, even although they carry some ore at the surface where they are discovered, the confined appearance they make being a great discouragement to the trying of them. I know very well that there is a kind of general aversion,

aversion, both among skilful miners and others, to the trying of these straight veins, even when they carry some ore at the surface; and I have seen a great number of superficial trials in such as carried some ore, but do not remember ever seeing a thorough trial made in any one of them. A little hole, five or six feet down, or a longitudinal slit, along the vein, perhaps not so deep, generally ends the trial. How far this may be right I will not positively determine; however, it may be proper for me to give my own observations upon a point of so much importance to the public, as these veins are very common to be found in all countries where the superficies of the strata are seen; and, in general I have observed that the greatest number of such veins as are roomy and capacious between the sides at a good depth, that is, from ten to twenty fathoms down, are generally very straight and close at the superficies of the strata; and besides such as I have seen in mining fields, I have examined great numbers of them in deep glens or gulphs, cut or scooped by rivulets in mountainous places, and upon the shores of the ocean in many parts of Britain, particularly round Caithness and other parts of the north of Scotland, round a good deal of the coast, and several arms or inlets of the sea in the Highlands of Scotland, and part of Galloway, in all of which places the
rocky

rocky cliffs are generally very high and clean, washed by the dashing of the waves ; and it is astonishing what a prodigious number of fine mineral veins are to be seen in many places upon those coasts, and many of them containing some ore and other good mineral symptoms, some of which I will point out hereafter. At present, let it suffice to observe, that the most of the veins which I have seen cut deep down by the water or otherwise, are narrow or close at the surface, and wider down below : At the same time it is also proper to observe, that it is very uncertain at what depth they begin to open. I have seen a great number of fine veins, with their sides perfectly close above, so as to appear at the superficies of the strata no wider than a common joint, the sides of the vein perhaps not an inch asunder, which, nevertheless, would gradually open downwards, until the cavity or body of the vein between the sides, at twenty or thirty fathoms down, would be six or eight feet wide, or more; and some of these veins which are close above and wide below, begin to open soon, that is, two or three fathoms below the surface ; others do not begin to open until they are eight or ten fathoms down : and, again, I have seen some which continued so close and straight for a great way down, that they would not be a foot wide at twenty fathoms below the surface, which, never-

theless, would open out to several feet wide at a greater depth.

These remarks seem to favour straight or narrow veins, and, in my extensive observations, I do not remember seeing many such as were close or narrow at the surface, which did not open below, if there was an opportunity of seeing them at a good depth.

There may be several reasons given for this species of vein being narrow above and wide below ; but these reasons will become obvious to the observing miner and the intelligent naturalist, when they come to read and consider the natural history of the phenomena of the strata in general, in the third part of this work, where I hope to make many circumstances evident, plain, and easily understood, which are now apparently very dark and puzzling.

I will now enter upon an exceeding difficult part of the task which I have undertaken, viz. to attempt a description of such rake veins as may very properly be called irregular ; and here I can only pretend to point out some few of the numberless irregularities and accidents met with in working such veins ; but they are found to be so Proteus-like, that it is almost impossible to describe minutely all their appearances, irregularities, and changes.

In this part of the natural history of mineral veins, I will begin with such as are very wide between the sides, but have good and regular sides, which the miners know where to find, though they are very far asunder; I do not mean here such wide veins as swell out suddenly into wide and irregular bellies, and soon contract again into much narrower compass; but I mean such wide veins as continue wide for some considerable length and depth before they are very much contracted by twitches, &c. Of this variety of vein, as well as all others, there are some of them quick and others dead, or some carry ore and others produce none, so far as they are tried; and again some produce ore in some places in working forward, or down in them, and in other places they are quite dead, and produce no ore at all.

One of the greatest points of difficulty in describing wide veins, is how to convey a proper idea of the various articles or mineral soils, hard and soft, and of the various figures and conditions of the ores found in such veins; for it would be a very easy matter to say that a vein is so many feet or yards wide; but the various phenomena of the inside of these veins, and of the soils or mineral matters they contain, is not easily described or conceived, without seeing them in their various appearances.

I observed before, that the two sides of a mineral vein are called by miners the hanger and ledger. These sides are always of the rock or strata which compose the mountain or mining field, the vein being a crack, breach, or fissure in those strata, the sides of which fissure are opened asunder to a vast variety of degrees. What is called dead veins, that is, those which do not bear ore at the surface, nor produce any upon such trials as may be made in them, frequently contain between their sides, in different places and in different veins, a vast variety of mineral stones and of softer mineral soils. The most common and the most promising of the mineral stones, as concomitants of ore, are the spars and vein-stones of different species. What I call vein-stone, is a compound mineral concretion, of various colours, appearances, and degrees of hardness, and not unfrequently of various colours in the same mass, though white often prevails.— This compounded stoney concretion is called by miners a *rider*, perhaps from its riding the vein, or separating it longitudinally into two or more divisions. This mineral stone is hard and heavy, sometimes compact and solid, but frequently cracked and cavernous, rising in irregular and misshapen masses, and generally exceeding hard. A rider frequently contains a variety of different substances or species, as well as different colours,

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in the same mass, such as spar, quartz, fragments of the rocks near the vein, sometimes pyrites, and often ore in grains and flowers, and sometimes different ores, as lead, copper, &c. in the same mass, and all these strongly coagulated or concreted together by a whitish or a brownish white substance, resembling quartz and agate, which seems to have enveloped the several articles in the composition when the whole was in a fluid state. I call this vein-stone, as I think the term should be the most intelligible to naturalists, it being always found in veins, upon the superficies of them, and in fragments and masses lying about upon the face of the ground, which have slid or been forced off the superficies of veins. But the vein-stone does not always contain so great a variety in its composition. It is often pretty white, and appears like a quartz concretion of a porous, or rather a cavernous texture; and the inside of the caverns, though small, frequently contain a brownish ferruginous soft soil, of a snuffy appearance; and sometimes the inside of these small caverns are finely lined with great numbers of pointed or prismatical crystals, generally exceeding beautiful, and sparkling like diamonds. But all the vein-stones, or riders, are not white nor whitish. In many places they are of a brown or a reddish brown, and several other colours; but the whitish colour

colour most commonly prevails. Strong wide veins often contain a large rib of this vein-stone betwixt the sides several feet thick; but in all degrees of thickness, from a few inches up to several feet, I have seen strong bold veins carry such a rib or body of this stone as to appear in a ridge above the surface of the ground a great way, the superficies of the native rock being withered and wasted away from both sides of it.

The next most common stone found in mineral veins is spar, of which there are several species, and these frequently tinged with several colours, and especially in veins which contain less or more of copper or iron.

The mineral spars may be divided into the calcareous and vitrescible, or, to speak as a miner, there are three different and distinct species of mineral spar, viz. 1st, the *calcareous spar*; 2^d, the *cauk spar*; and 3^d, the *quartzy spar*.

The calcareous spar found in lead mines is commonly, though not always, of a white and whitish colour, both the homogeneous and that which is mixed with ore and other mineral matter, unless it happens to be tinged or tarnished with soft soils, in which it is often found: I say it is commonly white, or of a bluish, a yellowish, a reddish, or a brownish white colour, frequently of a loose friable constitution, and generally of the same internal grain and texture as the ore
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it is mixed with, or which accompanies it in the same vein. Some of this spar is of a scaly and of a tabulated texture; some of it again is of a granulated texture, which appears uniform in the inside, and much of it is of a cubical or diced structure; some of larger, and others of smaller cubes, contiguous and slightly adhering to one another.

Cauk spar is not calcareous, nor is it generally of so pure a white as the calcareous spars. I have seen cauk spar of a dead white, but most commonly it is of a yellowish, a brownish, or a reddish white, or of a flesh colour: It is a dull ill looking spar, frequently rising in glebes and irregular masses, and so exceeding heavy, that miners have always imagined that it contained metal; only they think that the proper flux for it is not yet discovered. No doubt this mineral body is replete with the vitriolic acid and other mineral matter, which the art of the chemist may extract; at the same time, I think it highly probable that it is not a metallic ore. This spar being so very ponderous makes it very difficult to separate it from the metallic ores in dressing them.

Quartzy spar is generally of as pure a white colour as the calcareous, frequently more beautiful, and sometimes not unlike it in appearance; but it is of quite a different quality, as it will
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not effervesce with aquafortis, nor burn into lime, which are properties of the calcareous spar: On the contrary, instead of calcining, it vitrifies to a glass or slag in the fire. Some of this species of spar is found of a cubical and of a tabulated texture, resembling the structure of the common blue potter's ore; and I have seen much of it fine, smooth, and uniform throughout, without any visible grain or texture, and it is apt to shoot into prismatical crystals, which are commonly found pure and pellucid, so as almost to vie with the diamond in lustre, and frequently so hard as to cut glass.

Most of the mineral spars are frequently found shot into prismatical, cubic hexagonals, or other figures. These figured crystals are generally transparent and very beautiful. It is a great curiosity to behold the inside of some of the large cavities in which they are formed. These open caverns are frequently met with in hard mineral veins, and they are generally called by miners lochs or loch-holes.

The miners know nothing of these cavernous vacuities until they strike into them as they advance in working, and they are of various dimensions, from the bigness of a nut up to room enough for more than three or four men to turn themselves in them.

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The magnitude of these caverns is generally in some proportion to the capacity of the veins in which they are found, and the insides of them frequently exhibit all the variety, beauty, and splendour of the most curious grotto work.

There is commonly a hard concreted stony crust, called *druse*, adhering to the inside of the cavity, out of which, as out of a root, an innumerable multitude of short prismatical crystals are shot, which sparkle like a thousand diamonds with the candle, or when brought up to the sun. Between these clusters of mock diamonds, and sticking to them promiscuously, there are often ore, pyrites, and spar shot also into prismatical, cubic, and other figures; and besides these clusters of grotesque figures which grow out of one another, and are as it were piled upon one another, the whole inside of the cavern is sometimes most magnificently adorned with the most wildly grotesque figures, which grow upon, and branch out of one another, in a manner not to be described, and with all the gay and splendid colours of polished gold, of the rainbow, and of the peacock's tail, and all these blended together, and the masses reflecting all the beauty of such an assemblage of gaudy colours: But it may be remarked, that these caverns are never so magnificent and glorious but when there is less or more of yellow copper ore, or of the py-

rites in them, as these ores are found to produce in hard veins the most beautiful colours in the world. An eminent instance in proof of this assertion is to be seen in the copper veins in the parish of Colvend in Galloway.

These mineral loughs or caverns are the great source of materials for grotto work, and the specimens collected from the mines are generally the most showy dazzling articles in the whole arrangement of the splendid grotto.

Neither the calcareous nor the cauk spars will strike fire with steel, unless there is a mixture of the pyrites in them; but the quartz spars, on the contrary, gives fire plentifully. Pure quartz of a fine, smooth, uniform texture, breaking like glass, is often found in those mines where the quartz spars prevail, and it is frequently mixed with ore.

What I call pure quartz is a white, semi-transparent, hard and heavy stone, of a fine, smooth, uniform texture, and of considerable brightness, and not exhibiting any visible grain.

Quartz does not rise in blocks or large regular masses, neither in the mines nor any where else, it being full of cracks and flaws, so as to break into small irregular masses, with various sharp angles, and it is so hard as to waste the tools more than any other stone. Where quartz and quartz spars prevail, the veins are commonly

ly very hard and difficult to work, and it is as difficult to separate the ore from the quartz in dressing it, being so hard that it requires much labour to break the quartz mixt with ore small enough, and so heavy, that it does not easily separate. I will only give this specimen of such mineral stones as are most common and most generally known; there are a great many others found in different mines of various colours and textures too tedious to be described here just now.

The soft mineral soils are as various in quality and appearance as the hard. I will point out a few of them, in which I will make no choice or arrangement, but will give them as they occur to my memory. The *first* I will take notice of is a white or whitish mineral soil or clay, sometimes fine, tenacious, and smooth, but often more friable and coarse to the touch, not unlike flaked lime mixt with small sand. This species of mineral soil is frequently a promising symptom of lead ore; but I will leave the discussion of this point until I come to examine the symptoms and appearances of mines or good mineral veins.

2d, Red fatty clay in veins, which indelibly stains the hands and clothes, is an indication of iron, concerning which I will say nothing just now, but that the better sorts of iron ores are generally

generally accompanied with red staining softness, by which they are easily distinguished; at the same time it is proper to observe, that some lead and copper veins contain a considerable quantity of iron, and consequently of a red, or a brownish red soft soil, and especially near the surface.

3d, Bluish and greenish mineral soils, light and friable, and also heavy and tenacious.— These, and several others, will be treated of when we come to examine symptoms.

4th, Yellowish, ash-coloured, and marbled soft soils, or mineral clays, which are frequently not to be distinguished from surface clays of the same colours, but by the skilful miner.

5th, Black and blackish brown soft soils, commonly light and friable, though there are some of them more tough and weighty.

6th, The most remarkable and distinguished of all the soft mineral soils, and frequently the most promising, is of a brown colour, and of a lax and friable texture, often resembling rappee and other snuff in colour and appearance, being sometimes blackish, but generally brown, in all the degrees and shades of that colour.

Having given this brief specimen of the hard and soft soils which are most commonly found in mineral veins, I will now return to the history of the

the veins, and of the appearance these foils make in them.

It is very common to find a large body of rider in such a strong vein as the last mentioned in a rib, or standing in the middle of the vein like a wall, with a space between it and the sides of the vein. This rib of rider or vein-stone so situated divides the vein in two, as there is a space like a vein betwixt this rib and each of the real sides of the vein.

This rib or body of vein-stone may be, and frequently is, found of various dimensions, from five or six inches up to five or six feet thick. In strong veins, like the one presently under consideration, it is not uncommon to find a body of vein-stone several feet thick. Sometimes this vein-stone is richly flowered, spotted, and veined with ore, and sometimes there is little or no ore found in it; and it frequently happens that when it is mixed with some ore, it is found in such small specks and threads, and the stone is so hard, that it is not worth separating. This rib of rider in a strong vein is not always found in the middle of the vein, but is frequently found nearer to one side than the other, and it is not uncommon to find it adhering strongly to the side, and mixed with ore. When a rib or wall of rider is situated in the middle of a wide vein, there is sometimes good ore found upon each side of it,
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and at other times upon one side only ; and this ore is found either in a continued rib or discontinuous masses.

When the ore is found in ribs betwixt the vein-stone and the real sides, these ribs of ore, as well as that of the stone, are of various dimensions, from two or three inches up to two or three feet or more in thickness. In strong wide veins, which have a rib of rider in the middle, it is not uncommon to have a rib of good ore upon each side of the rider, of one, two, or three feet thick, though it is not commonly found so thick upon each side ; but it is common to have a rib of two or three feet thick, or more, upon one side of the vein-stone, and a thin rib upon the other.

These continued regular ribs of ore which are found in wide veins, running parallel to the rib of rider, and betwixt it and the sides of the vein, are sometimes solid ore and sometimes mixed with spar and other heterogeneous matter ; and it often happens that ore, found thus betwixt a rider and the side or sides of the vein, is partly solid and partly mixed.

Again, the ore found betwixt a rider and the sides of a vein, is not always in regular continued ribs. It is sometimes found in a discontinuous rib or ribs, that is, in large flat slabs or masses, which appear like a rib for two or three feet, perhaps
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for five or six, every way, and then you come to the end of it, if you are working forward horizontally, or to the bottom of the mass, if you are sinking down in the vein; but then you are not long before you touch the edge of another cake of this discontinued rib. These cakes, or flat masses of ore in the discontinued rib, are of various sizes, some being very large and others very small, and the distance betwixt them is as various as the dimensions of the masses. In different veins, and in different parts of the same vein, the masses are so near one another as sometimes almost to touch, and at other times there will be a distance of from a foot to five or six feet between the masses, and frequently more; but this distance is exceedingly variable, even in the same vein, and often at no great distance.

It is proper for me to observe here, that these discontinuous ribs of ore are imbedded in one of the soft mineral soils mentioned above; that is to say, all the masses, or slabs of ore, are encompassed with soft soil, and the same softness continues betwixt mass and mass; and it is further to be observed, that although the rib is really discontinued, and that there is less or more space betwixt the different masses of ore, yet the several masses are thinner and thinner towards the edge of the mass, and do not break off at once when at full thickness. The discontinuous, as
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well as the continued and regular ribs of ore, are of various dimensions or thickness, from an inch up to two or three feet or more.

A discontinuous rib of ore may be, and often is, found every way as described above, in a vein, without any rib or continued body of rider. Again, the ore is frequently found betwixt the rider and the sides of large roomy veins, in glebes and irregular masses of various sizes and dimensions, imbedded in, and surrounded with softness. Some of these roundish masses are no bigger than eggs; others are so large as to produce several tons of ore out of the same mass; and they are like stones in a brook, of all the intermediate sizes.

Rider in a vein is not always found in a continued rib, no more than the ore. It is frequently found in a discontinuous rib; sometimes in a vein that is more hard and close; but generally amongst softness in a vein that is loose and open; and moreover, rider is not only found in ribs of several dimensions, and in several degrees of continuity, but it is also found in larger and smaller glebes, and irregular masses. These glebes and irregular masses of rider or vein-stone in wide, soft, loose veins, are found of all dimensions, from the size of the fist, up to the size of a hoghead, and much bigger. In some very wide loose veins, irregular masses of rider will be found in one side
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of the vein, and irregular masses of ore in the other, and both the masses of rider, and those of the ore, lying without any order among soft loose mineral soil, and without the least appearance of continuity: Sometimes the masses being pretty near and contiguous to one another, and sometimes the miners have to work forward or downward several feet of the soft soil before they touch one of them.

These large masses of rider are frequently so very hard, even among the excessive softness of the loose soil which surrounds them, that they cannot be broken to pieces with any tools and strength of men without gun-powder. These masses of vein-stone, found loose and detached among softness, are of all colours, as white, yellow, red, brown, black, green, and ash-coloured, in all their shades and varieties, and frequently several of these colours are found blended together in the same mass. These masses of rider lodged in softness in wide loose veins, are sometimes poor, sometimes rich in ore, and they are frequently found to contain none at all. When they are poor in metal, they are then to be called riders mixt with ore; but when they are very rich in metal, they may be called masses of ore mixt with rider. It is not uncommon to find these riders mixt with several species of ore in the same mass, as, for instance, lead, copper, iron,

pyrites, &c. which mixture generally renders them all very useless, the riders being often so hard that it is not easy to break them small enough for separation, and the different ores so mixt and combined together, that clean ore can hardly be made out of any one of them.

Again, wide, soft, loose veins sometimes only produce larger and smaller masses of ore without any rider at all.

The dimensions of these glebes and masses of ore in soft wide veins cannot be determined. It is common to find detached bits amongst the soft soils as small as pease, and even smaller, but generally so coated over as to be imperceptible, until they happen to be crushed or bruised between two hard bodies, when their bright metallic quality appears. Bits and masses are commonly found detached and surrounded with softness as big as eggs and less, as big as the fist, the head, and so on, up to large unweildy masses, which cannot be stirred from the place where they are found, but must be wrought out piece-meal; and in some very wide soft veins, they sometimes meet with masses so large as to produce a great many tons of lead out of one lump.

These larger and smaller lumps of ore in some soft works are all pure and solid; in others, they are less or more mixt and blended with spar, rider, stone, and other heterogeneous bodies. In
some

some soft veins, pure and mixed masses of different species of ore are found, such as lead, copper, iron, &c. ; and there are often found in the softness masses of all sizes of different kinds of stone, besides spar and rider; and every substance found in the inside of these soft loose veins generally has the appearance of being corroded and wasted, the masses large, and small, of ore, and others, being of no determined or regular shape, but having much the appearance of some degree of corrosion, and a partial wasting as they harden, they generally having a lax texture and appearance like flaked lime or snuff. I hinted before that the lax dusty soils are of various colours, though a snuffy colour or darker brown are the most common. These soft lax soils are called *mother* by Scots miners, and where discovered in a vein, they are generally reckoned a good omen both of lead and copper. Some soft loose veins, nevertheless, contain a great quantity of these soft soils without any ore, so far as they are tried, and there are often considerable trials made in it, the soil being reckoned so fruitful of ore, and so often to accompany it, which often proves a temptation or inducement to go on.

The phenomena of the inside of these veins are so various, that it is almost impossible to go through every point of description; and, therefore,

fore, I will now proceed to observe, that all bold wide veins are not soft. There are many of them very hard. The hard wide veins are also various in their appearances and in their contents. Some of these bold veins have produced great bodies of lead ore. At Llangunog in Wales, they had fifteen feet wide of ore, besides several feet more which was mixt with spar, rider, &c. ; and from the reports of tradition, which are corroborated by circumstances, it appears they had ore of great width at Strontian, in the Highlands of Scotland, in the York Building Company's time, and ore of great width has been wrought in hard veins in several other parts of Britain. They had solid lead ore of six feet wide at Wanlockhead in Scotland when Mr Telford had those works. I saw it afterwards four feet wide of fine solid ore in the same vein. They have frequently had remarkably rich lead ore in several veins at Leadhills ; and it is said to be up to fourteen feet wide of solid ore at present in one of those veins ; and four, five, or six feet of solid ore in hard veins, and sometimes much more, has been no uncommon phenomena in several parts of England and Wales.

But the cavities, or rather the space betwixt the sides of bold hard veins, are not always filled up with pure and solid ore ; it may rather be asserted that such a thing seldom happens. They
generally

generally contain, besides the ore, a great quantity of rider, spar, and other hard matter.

Wide hard veins frequently carry a strong body of hard rider of several feet, and sometimes of several yards thick. In some places a rib of ore is found upon one side of this rider, and in others upon both sides of it; and it is but too common that none at all is found, neither upon the one side nor the other.

Hard bold veins, containing no metal to begin with, are very discouraging for mineral trials, the ground being so very difficult to cut, that trials in them soon become very expensive; but sometimes this difficulty is in part removed by a thin strake or seam of clay betwixt the rider and the side or sides of the vein, which miners call a *steeking*, and which helps them forward greatly, as they cut this out first the length of a pick helve, which frees the *hards*, and makes it easier wrought with gun-powder or otherwise.

It is almost as difficult to describe the inside of a hard vein as a soft one, as the riders, spars, and ores appear in such a variety of conditions and mixtures in different veins.

I observed above that some hard veins carry a rib or body of rider, with a rib of ore upon one or both sides of the rider. These ribs of ore are of various dimensions or thickness, from less than one inch up to three, four, or five feet; sometimes

Sometimes these ribs of ore, running parallel to a rider in hard wide veins, are fine and solid, but they are more frequently found mixt and debased with spar and other heterogeneous matter. It is not uncommon to find no ore in one of these hard veins, but what is mixt and blended with a prodigious body of strong rider of great width, which, at any rate, is very difficult to work; and, therefore, the ore must be in considerable quantity when so mixt to defray the expences of raising and dressing it.

Again, some wide hard veins have little or no rider in them, but contain a considerable body of ore mixt with spar of several feet thick.—Some of these wide veins of ore mixt with spar are pretty rich in ore, so as to be worth working with profit; others, though wide, are hardly worth working, and many of them are so poor in ore as to be worth nothing at all; and there are some wide bold veins which contain a great body of spar, as there are others of rider without any ore at all.

And again, there are some bold regular good like veins, containing a considerable quantity of ore, which is all spoilt and rendered useless by its being blended with a great body of cauk spar, from which it cannot be separated with moderate expence; and some good veins of ore are spoilt and rendered useless by being mixt with a great quantity

quantity of pyrites, or mundic, as it is called by Cornish miners. There is sometimes a rib of three or four feet or more of the pyrites found in a wide vein, with a considerable quantity of fine lead ore.

If the lead ore happens luckily to lie in a rib, or otherwise, in one side of the vein, it may be wrought with profit; but if they are blended together, it is ten to one that the lead is not worth working; the mundic or pyrites being so ponderous that they cannot be separated to advantage.

Wide sparry veins sometimes carry two or three or more ribs of ore, separated from one another by so many ribs of spar; which are not always worth working; for it too often happens that when ore is in this or any other way divided, it is rendered unprofitable; however, this depends upon the quality and goodness of the ore. If the ribs are each of them some inches thick of pure solid ore, they may work very well, but sometimes such divided ribs are not above one inch a-piece, and even less.

I have dwelt long upon what may be called regular veins, and yet I have not finished their history; a great deal more may be said about them, but that I may not be unprofitably tedious, I will remark here in general, that every word I have said about wide veins, hard and soft, might be repeated in giving the history of those which are in
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all degrees narrower. The ore, the spars and riders, and all the soft foils with and without ore, appear exactly in the same manner in the middling and lesser veins as in the large and wide ones, only allowing for quantity. There is not so much room in the lesser ones as in the greater; but they contain the same articles, and they are compounded and disposed alike in each; and therefore I will refer to what I have said about the large and wide veins, to serve for the history of the middle and small veins.

I will now proceed to give some account of such rake veins as may be called irregular; and these are, 1st, Such as open suddenly into very wide bellies, and close or check again as suddenly: 2^d, Waving veins, or such as open and close alternately at very short distances, as you work forward horizontally in them; and, 3^d, Such rake veins as have a very great hade or slope, which is a sufficient irregularity of itself, and besides these, are apt to be very irregular in wideness. These three are only varieties of the same vein; and, indeed, the varieties are so many, that it would be exceeding difficult to describe them all.

Some hard veins come under the description of these three; and it is not uncommon to see a pretty wide and rich belly of good solid ore, which does not continue for any considerable length, as
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you work forward upon the bearing of the vein, but soon checks or twitches out by the sides of the vein coming together as you advance horizontally. By "soon twitches out," I mean, that it fails at the end of a few fathoms, where the sides of the vein come together, either suddenly, or more gradually; and the twitch, when the sides of the vein come together, is either total or in part. Some of these twitches carry a small rib of solid ore quite through, until the vein opens again, and produces another belly; and in other twitches, we have a rib of rider going quite thro' the twitch, and this rider is sometimes mixed with ore, and at other times it is quite barren; and again, in many of these twitches we have neither ore nor rider, but in some of them the sides of the vein are squeezed as close together as a joint between two hewn stones, and in others there is nothing but a thin strake or seam of clay, perhaps not an inch thick, or not above one or two inches at most. Miners call this thin seam of clay a *Sticking*. When there is either a thread or small rib of ore, pure or mixed with spar or rider, or else a rib of barren rider leading through the twitch, or again, where there is a sticking of clay, there is no difficulty in the case, except in point of labour and expence; an unexperienced miner may find his way through the twitch well enough; But where the sides come perfectly close, and are

run or cemented together, which is often the case, it then requires the care and attention of an observing experienced miner to keep the vein with certainty as he drives through the twitch, and especially if it proves a long one.

In general, the veins do not close at once when one of these twitches are coming in, but the belly of ore begins from the widest part to wear gradually less and less, until at last the sides of the vein are come pretty close together, and the ore wears out to a point or thin edge, and is in some twitches squeezed out altogether, and in others to a small thread or rib which goes through with them. These twitches are of various lengths.

No miner, when his vein is checked or twitched out, can possibly tell how long it is to continue twitched, or, in other words, how many fathoms he has to drive through it before the vein opens again, unless he cut through the same twitch before, either higher up or lower down; and this uncertainty of the length or extent of twitches is one of the most puzzling dilemmas, or greatest difficulties met with in the practice of mining. Some of these bars betwixt bellies, or wide places in a vein, will not continue above two or three fathoms before the vein begins to open again upon the other side; but others will continue for ten, twenty, thirty, or forty fathoms, and even up to sixty, eighty, and a hundred fathoms,

or

or more ; so that we are frequently in a sad dilemma, when we have driven ten or fifteen fathoms in an unknown twitch, and it is very hard to determine whether we should push forward or stop short. When the miners have cut a drift through a twitch, the vein begins to open, and the sides to part asunder upon the other side. If they had a thin rib of ore to lead them through the twitch, it begins to grow thicker ; but if they had none, they first touch the thin edge of it. Perhaps they first touch it at an inch thick, or even less ; but as they advance forward, the ore increases gradually, and grows better and better, until they come to the best and widest part of the belly, as a fish's tail increases gradually from the point forward to the thickest part of the body.

These bellies of ore are of indeterminate dimensions both as to length and breadth or thickness ; some of them are but a few fathoms long in all, others continue for a great many fathoms ; some continue at full wideness where the ore is best for several fathoms, and others begin to dwindle or wear thinner almost as soon as you arrive at the best and thickest part of the belly, and again they vary as much in width or thickness as in length, as they are found in different veins, and sometimes in different places in the same vein, from a few inches up to several yards wide. It sometimes happens, that the miners meet with a false appearance

appearance in driving through a twitch, that is, with a small quantity of ore, which does not continue, neither as they advance, nor up and down; but they soon lose it again, which proves a great disappointment, as they naturally expect, in such a case, that they have got hold of one edge of a belly of ore, and it proves a false belly, or only a small nest.

When one belly of ore proves pure and solid, it generally happens that all the bellies prove so in the same vein, and especially in the contiguous parts of the mining field. The contents or produce of a vein frequently change greatly at a distance.

I have, as yet, in this vein only mentioned solid bellies of ore; but it must be observed, that where ore is found in this description of vein, it is not always solid; on the contrary, it is oftener found mixt with spar and rider, than solid; and too often these bellies in this sort of hard vein only contain spar or rider, without any ore, or so little that it is not worth working. It is in these veins that the open cavities spoken of above are most frequently met with, many of which are exceeding curious.

I hinted before, that the miners know nothing about these loughs or concavities, until they strike their tool into one of them at once, nor do they know any thing about the dimensions of them
until

until they open them up; for they are, as I hinted, of all dimensions, from the size of an egg and under, to the size of a small house. Miners like well to meet with these concavities in hard veins, and especially after driving a long time in a hard check or twitch, as one of these latch-holes proves the first and surest indication of the veins beginning to open again, and of another belly of ore coming in. When this species or description of hard veins are barren of ore, the spars and riders, &c. are found in bellies in them, in like manner as the ore is found in the bearing veins; and these barren hard soils begin and end in a narrow or thin edge at the extremities, and swell out gradually in the middle of the belly, exactly as the ore does, and the checks or twitches are the same in the barren as in the bearing veins. Sometimes a thin rib of the spar or rider they contain leads through the twitch, and sometimes a thin sticking of clay, or else the sides of the vein are found squeezed close together, as described before.

This species of big bellied veins are as often found soft as hard; but the soft bellies are much more difficult to describe than the hard, and likewise more difficult to work.

The soft soils found in the bellies of this sort of vein, are much the same as we described in the soft and wide regular vein; and the ore is found
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in them much in the same manner, excepting that there is no regular ribs found in these bellies. The ore in these wide and spacious cavities or bellies of these soft veins, is generally found in glebes or irregular masses, frequently of a glebous, roundish, or oval figure, and of as various dimensions as can be imagined, surrounded with, and buried in soft soil.

I observed of the hard veins of this description, that the bellies of ore, or of spar or rider in them, swell out sometimes to several yards wide in the middle of the belly; but some of the cavities or bellies of the soft ones prove a great deal wider. It is no uncommon thing in North Wales, and many other places, to find the soft openings in this sort of vein swell out to an enormous wideness, so as sometimes to make it difficult to find the real sides of the vein, and sometimes the real sides are shaken and loose, occasioned by the softness of the soil within the real sides yielding to the pressure of the sides. Working these soft veins is the most difficult part of mining. There is no advancing a foot in these, without advancing square timbers as far as they go, in form of a trance or passage in a house; each pair of which timbers are composed of two door-cheeks, or side-posts, and of a lintel and sole-tree.—The miners stand within this square timber when they

they work, and still set more timber as they make room for it. This is expensive, troublesome, and dangerous, if they have not good skill in setting the timber, for the soil is generally quite soft and loose; and being commonly mixt with lesser and greater glebes and masses of ore and stone, the whole will frequently rush down with violence before their timber to a greater height than they incline. A skilful miner does all he can to prevent the soil from running or washing down before his timbers, by driving in polins or sharp pointed stakes. He enters these above the lintel or head-tree, and without the side-posts of his foremost pair, and with his mallet drives them forward, past the square timbers, into the softness; and if a mass of ore, or any other hard substance, retards the point of one of his polins, he draws it out of the way with his pick; and when the end of his polin is freed, he drives again until it is far enough up; and when they are all driven as far up or forward as is wished, he then works out room to set another pair within those polins, and enters another course of polins, and so on; and whether they advance horizontally, sink down, or rise upwards in these soft places, they must do all with square timbers, which is very troublesome and expensive; but it frequently happens that the ore is so plentiful

plentiful and good in these veins as abundantly to compensate all this trouble and expence.

I hinted above that these spacious bellies in soft veins frequently contain glebes and masses of ore of various sizes. Sometimes these glebes of ore are pretty large, and the concavity of the vein pretty full of them, intermixed with a lesser quantity of soft friable mineral soil, and sometimes there is less or more space between most of the glebes ; in which case the miners have a considerable quantity, and sometimes a great quantity of the soft soil to work out, in proportion to the quantity of ore produced. In some parts of these veins they meet with very large and very small glebes of ore, and with all the intermediate sizes, exactly as they are found in the wide and soft regular veins described above, excepting that no regular ribs of ore are found in these irregular bellied veins ; and it is not uncommon to find in the soft opening of one of these irregular veins a single mass of ore so large as to take a considerable time to work it out, and to prove a great treasure to the proprietors.

These enormous masses of ore are by some miners called bellies of ore ; but properly speaking, the belly is the sudden dilatation or opening asunder of the sides of the vein to a great width, and when they contract or come together again as suddenly.

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The glebes of ore found in the soft bellies of these irregular veins are commonly solid and good, that is to say, pure and unmixed with spar and other heterogeneous matter; and such pure and solid glebes cost but little trouble and expence in dressing and preparing the ore for the furnace, and they generally yield a good produce in smelting. But they are not always so rich,—sometimes spar, &c. is mixed with them, which makes it necessary to break the most of them down small in washing and dressing the ore, and then the produce in smelting is seldom so good as when the masses are solid.

The glebes and masses of lead ore which are found immerfed among soft soils in the cavities of soft mineral veins, are of various colours and appearances. In many soft works, the glebes of ore are all coated over with a white substance, resembling lime to look at; but this white scurf is a kind of native ceruss or efflorescence, occasioned by corrosion, or beginning decay of the outside of the masses. Bits of lead ore lying a long time above, gather the same sort of scurf, which undoubtedly is occasioned by the moist and corrosive quality of the atmosphere; and such bits exposed a long time to the influence of the external air, would, in the course of time, be altogether wasted away by it.

In some soft works there is great appearance that the masses of ore below ground are also corroded, and part of them wasted away, as some of them are found cavernous, as it were honey-comb'd, and of very irregular figures, and of as irregular sharp angles, points, and edges, the cavernous and honey-comb'd places containing a blackish or a brown ferruginous powder; and the whole of the soft soil in which such masses are immersed, has generally a ferruginous appearance, and is of a lax and friable texture. These seemingly corroded masses of ore are not white like those mentioned above, but are generally of a brown or a blackish brown hue on the outside.

Again, in some soft works the masses are outwardly of a dull, tarnished, leaden hue, though inwardly, when broken, of a bright, lively, blue colour.

The most beautiful masses of lead ore I ever beheld was a few years ago at Leadhills in Scotland. I was then riding through Leadhills in haste, without the least intention of stopping, when a singular appearance of a fine, bright, yellow colour at some distance attracted my notice. I went up to it, and by some little breaks in some of the masses, I saw it was a rich heap of fine lead ore, lying upon a shaft head, just as it had been drawn up out of the works, which ore I viewed

viewed and examined a while with great pleasure and admiration. The masses of ore were pretty large, few of them being less than one hundred pounds weight, and many of them much more; and the outside of every one of these masses was of the brightest and most beautiful yellow colour I ever beheld, and the inside of each of them was a bright blue, the common colour of lead ore. Upon nearer inspection, I found this glorious colour to be a rich efflorescence upon most of the masses; this yellow efflorescence was near an inch deep, of a fibrous, columnar, or striated texture, the columns shooting out regularly from the mass all round it, and all of them disposed perpendicularly, and parallel to one another. In short, this was an exceedingly curious, and a most beautiful natural production.

Perhaps there seldom has been seen a richer bloom or flowers of lead. I was sorry to find no person in sight, and time would not allow of my turning back to the mining village, to enquire about the nature and appearance of the bed or soil in which this curious ore was found, though I know from the appearance of the masses, which were all whole and unbroken, that it must have been found in softness.

I have seen the masses of ore in some soft works of a red colour. This happens when the clay or soft soil contains some iron, and there are several
rich

rich lead veins which hold a quantity of iron, both in a hard and soft state, and sometimes too much, so as to render the lead unprofitable.

It is not uncommon to see the masses of lead, when drawn out of soft works, of the same colour as the clay, or other soft soil, in which they were immersed in the vein; and as the colours of these are various, so must the colours of the masses likewise be; but I have given sufficient examples, and, therefore, I will drop this point of description.

The second sort of irregular rake vein I am to describe is what I call the *waving vein*. This is a rake vein or perpendicular fissure, which opens and closes at very short distances. This vein is very near a-kin to the last described, as it consists of bellies and twitches; but the twitches are so numerous and so near to one another, that there is not room nor distance enough between them for any of the bellies in this vein to open out to any considerable wideness; and of consequence this vein is never so rich and valuable as the last mentioned, there not being room enough in these small cavities or openings for any considerable quantities of ore.

As the concavities or bellies in this vein are small and of short continuance, so it generally happens that the twitches or grips between them are also short and of no great continuance; and as the

the small openings and twitches are so frequent and near to one another, I call this the waving vein, as the small bellies in this vein resemble the hollows between the waves on a pool of water.

I have seen both lead and copper veins of this description, but I have not yet seen any of them produce a great quantity of ore; and as the sides of these veins are so distorted by being so frequently squeezed together by the numerous twitches, it generally happens that the masses of ore and other mineral soils found in them are tortuous, twisted, and irregular.

The third irregular vein of the rake species is that which has a great hade or hang. It may be proper to observe, that the perpendicular figures or rake veins have a greater or lesser hade or slope in proportion to the declivity of the strata, as the mineral fissure, or vein, is a transverse section cut at right angles to the lay or bed of the strata; that is to say, when the strata are perfectly flat or horizontal, then the mineral fissures we call rake veins are perpendicular; when the strata decline one or two degrees from the horizontal flatness, then the vein will have a slope of one or two degrees from the perpendicular. Let us suppose, for example, that the strata cut by a rake vein have a declivity to the south of two degrees from the horizontal line; in that case, the vein which cuts these

these strata will hade or slope as you sink down in it two degrees from the perpendicular towards the north. If the strata dip suddenly to the south, and the declivity is so steep as to be near the angle of forty-five to the horizon, the hade or slope of the vein shall be upon the angle forty-five to the north, or near it, as these veins generally cut the rocks at right angles to the beds of the strata, or nearly at right angles; and therefore whatever be the slope of the strata one way, the hade or slope of the vein is as much from the perpendicular the other way: But then it is also necessary to observe, that this can only be said of that rake vein which runs parallel to the bearing of the strata. There are north and south, and east and west rake veins, or what is called so by miners, though they seldom answer exactly to these points. The one of these cut the rocks in a line parallel to the bearing of the strata, and the other cuts right across the strata; so that these two veins intersect one another at right angles. Now the general bearing of the strata in Great Britain, and in all countries under the same parallels of latitude, is nearly from north-east to south-west, consequently the parallel veins, or those which cut the rocks in a line parallel to the bearing of the strata, must point towards the south-west and north-east, or thereby; and those which cut across the strata, and intersect the parallel veins, must
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run or point from the north-west towards the south-east, or thereby, where the bearing and declivity of the strata is not warped by any accidental cause, but is fair and regular, according to the general course and lay of the strata in the island.

There are also other rake veins, besides the parallel and rectangular ones, which cut the strata in a diagonal line across the slope or declivity. These I call, for distinction sake, *oblique veins*. Now where the beds of the strata are nearly flat or level with the horizon, all these three veins may stand nearly perpendicular ; but where the strata have a great hang or declivity, the parallel and the oblique veins will likewise have a great hade or slope the contrary way, though the rectangular vein, or that which cuts the strata in a right line across the bearing, may be nearly upright, when the others have in course a great hade. The veins I call oblique cut the strata in all directions across the slope ; of consequence, they either come into or intersect the parallel and the right-angled veins in all directions. I shall have occasion to examine the course of the oblique vein hereafter ; and therefore I will drop that part of the history of it here, and will proceed to give some account of such rake veins as have a great hade or slope.

I observed before, that the right-angled veins, that is, such as cut the strata right across, or in a
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right line from crop to dip of the strata, are generally more upright, or nearer the perpendicular position, than the parallel and oblique veins. I explained before, that these last mentioned veins are nearly upright only when the strata they cut are near the horizontal position; but when the strata hang considerably towards any point, the parallel and oblique veins have also a considerable hade or slope, nearly in proportion to the declivity of the strata; and it is these two veins that come under the description of such rake veins as have a great hade or slope, and therefore deserve to be called irregular veins. These veins are generally very troublesome to work, on account of their great hade, and of the irregularity of the hade, as these veins frequently vary the slope; and besides the frequent variation of the slope or hade of these veins, which is of itself a sufficient irregularity, the two sides, or hanger and ledger of these veins, are also generally very irregular. The hanging or upper side of them sometimes rises up into a concavity, quite out of the regular flat course of it, and sometimes again it falls down to a convexity, and if the rock, which is the subject matter of this side, happens to be any way lax or tender, then this hanging side comes to be very troublesome, expensive, and dangerous, and requires much timber to support it, even where the vein may be called hard; and if the

the vein happens to be soft, it is still worse to support this hanging side. The ledger, or lower side of this vein, is also irregular, falling into concavities, and rising up to convexities.

The natural hade or slope of these veins makes them abundantly troublesome to work, and these additional irregularities of the sides make them still worse. The greatest and most peculiar difficulty in working these veins, is in getting the work out of them; but as I shall perhaps have occasion to mention them again in another part of this work, in order to enquire into the best methods of bringing out the work, I will dismiss them here, after observing, that these irregularities of the great degrees of slope, and of the convexities and concavities of the hanging and ledger sides, are over and above the irregularities met with in other rake veins, such as bellies, twitches, &c.

I have dwelt the longer upon the history of the rake vein or perpendicular fissure, because it is the most common and frequent of all veins, and almost the only one as yet wrought in Scotland. I should now proceed to the history of the pipe vein; but before I begin with it, I think it is proper for me to give a brief account of some of the strings, and other partial veins which branch

out from the principal ones, as these properly belong to, and accompany the rake veins.

A string, in mining, is a discontinued vein or mineral fissure, which flies out in a right line, but with an acute angle from the principal continued vein; and when it has stretched in that line to an indeterminate, though no great distance, it then terminates in a point, and is squeezed out to nothing by the two sides coming close together, coalescing, and having no marks or vestige of a vein; or in other words, it is really the one end of the crack or fissure, and further forward, the stratum or rock is whole and unbroken. The other end, as hinted already, joins the principal vein somewhere, and comes into one side or other of it in an acute angle, but does not cross it; if it crosses the vein, and is found quite through upon the other side, it is not a string, but an oblique or diagonal vein. When a string has really joined and is come into a vein, they are afterwards in that line no more two but one; the line of the string, and the string itself, being lost in the vein, and the vein only continues the line of bearing. These strings fly out from the veins in all directions, though always diagonally; and they are sometimes as rich, and I have seen them for a short time even richer than the vein itself; but they at last squeeze out, and come to
nothing

nothing at a less or greater distance. The rest of the history and description of a string is the same as that of a rake vein or veins as above, to which I refer, to prevent tedious and unprofitable repetition.

There is another species of string which has no relation to, nor, perhaps, is not near any vein at all. This species of string is, properly speaking, an imperfect discontinued vein, which neither puts down to any considerable depth, nor does it stretch forward to any considerable distance upon the line of bearing either way; nevertheless it may, for a short time, look as well, and produce as good ore, and other mineral soils, as a real continuous vein.

The mining field in the island of Isla, upon the west coast of Scotland, is remarkable for a great number of these strings, or imperfect discontinued mineral fissures; some hundreds of which produced, and now contain, some small quantity of good lead ore, and yet certainly come to nothing at the depth of a few feet, or a very few fathoms, and at no great distance in the line of bearing; and that not by a twitch and such a coalescence of the sides of the vein as will open again further forward in the line of bearing, which is an accident common to all veins, but actually by the discontinuance of the crack where the
strata

strata appear as whole as a number of unbroken planks lying one above another.

As I have named the island of Isla, it may not be unprofitable, and it may gratify the curious, to give a brief history of the mining field in that island.

The mining field in Isla is wholly, or, at least, chiefly comprehended, or included in a patch of limestone; I call the limestone of Isla a *patch*, because it covers but a small part of the island. The lime field in Isla is compact, or nearly as broad as long, and is somewhere about ten miles over every way; but perhaps the world does not contain a patch of stone of any kind which exhibits a greater number of mineral veins; and it is remarkable, that they almost all bear some good lead ore quite up to the day.

The lime rock in Isla is mostly bare, excepting tufts of grass, and little spots of arable ground about half an acre less or more here and there. The superficies of the lime rock being so generally seen, has given opportunity for discovering such a vast number of mineral veins: Among these there are a great many north and south, and a great many east and west veins, or what are so called, which cross and intersect one another nearly at right angles; and, moreover, there are also a great many oblique or diagonal veins, which cross and intersect the others at all manner of acute

acute and obtuse angles : And it is worthy of remark, that besides the mineral veins, there are also an innumerable multitude of whin-stone dykes, of all sizes and dimensions, which cross and intersect one another, and which cross and intersect the mineral veins in all manner of directions, so that the whole patch of lime is curiously cut and divided into an innumerable multitude of compartments, or angular pieces of all dimensions and figures, only that none of them can be very large.

Some of the whin-dykes are not a foot thick, others are two, four, or six feet thick, and again several of them are eight, ten, or twelve feet, and some few a great deal thicker. Many of these dykes or ribs of stone run parallel to one another, and cross and intersect one another. Great numbers of these ribs of stone rise up into ridges above the surface of the ground, the lime being weathered, decomposed, and washed away from both sides of them, and the whin being very hard, stands the weather better than the superficies of the lime. I have stood upon an eminence or rising ground there, and seen some scores of these whin-dykes in my view, crossing and intersecting one another in all directions. The quality of these whin-dykes is generally a species of that hard stone which naturalists call *basalts* ; but as I am to give the natural history of the *basalts*,
and

and of the whin-dykes, in the third part of this work, I will say no more about them here, but just observe, that they are all mineral veins.

I am very sensible that the most of miners will startle at this observation, and will be loth to own that they are mineral veins; however, I expect to make it abundantly evident, that they were originally the same sort of fissure, though filled afterwards in whole or in part with matter foreign from what is called mineral matter. I said *in whole or in part*; and as a proof of my being right, ore has been found upon one or both sides of these ribs of stone; as an instance of this, Charles Freebairn, a late lessee of the mines of Isla, had a rib of solid lead ore for some short time about three feet, and for a longer time about two feet wide, running parallel to one of these ribs of stone in the same vein, and quite close to it; and deeper down in the same vein, he had a considerable wideness of soft mineral soil, with some lead ore in it, upon the other side of the same rib of stone. I examined this vein myself, and investigated the truth of the circumstances, only I did not see the ore at its full wideness; but both the master and the miners assured me that they had it so wide some time before I was there; and, moreover, I saw both ore and mineral soil upon one side of some, and upon both

both sides of others, at the surface of the ground in other parts of this mining field.

I observed before that this mining field contains a great number of good north and south veins, and likewise a great number of good east and west veins, all of which cut and intersect one another nearly at right angles; that there are also a great number of diagonal veins which intersect the others at various acute angles, besides prodigious multitudes of strings and imperfect veins, numbers of which branch off from the principal veins, and others are quite detached from them; and it is a true, but surprising fact, that some hundreds of these veins, perfect and imperfect, have been tried, and some lead, less or more, found in them all.

The phenomenon of such prodigious numbers of superficial trials within so small a compass of ground, not above ten miles over, struck me with surprise, and, therefore, I made some enquiry about it, and I was informed, that some time ago a company of Glasgow merchants took a lease of this mining field, and their method of working it was as singular as it was pernicious to the future welfare of the mines. Whether I was told that they had any practical miners there or not, I do not now remember; however that may be, their principal way of procuring ore was by employing and encouraging the peasantry of the island

island to dig and raise the ore at so much per bing, which is a certain weight or measure ; and in consequence of some ore being seen at the surface in numbers of veins, the country people searched, dug, and rummaged the whole face of the mining field. They laid all the veins open to the day, like a trench or ditch, where they found any ore. In some places they did not go down above two or three feet in the veins and strings, at most not above two or three fathoms, when they generally came to more water than they could cast out with a dish ; and as they had no pump, windlafs, nor other apparatus for drawing buckets, they could neither bring out the water nor the work to a greater depth conveniently than about two or three fathoms.

No doubt this imperfect method of rustic mining would produce a considerable quantity of good ore for the time ; however, it had a most pernicious effect upon the mining field for the future, as they went down every where in ore as deep as they could for water ; and as they cut up the veins along open to the day, they are now so many wet ditches, which receive all the surface water, which conceals the ore they left in the soles, and it is not easy getting down to examine it in a long ditch of water. However, several of them have been examined, and very good ore found in some of the veins, and smaller

ler ribs of good solid lead ore, from three to six inches, have been seen in the soles of numbers of these superficial old works.

I laboured very hard about three weeks in the island of Iſla, viewing and investigating the mineral appearances, and declare I never saw, nor do I ever again expect to see, so many good and regular veins so near to one another, in many of which good ore has been found and wrought; and there is ore very well worth beginning upon in the soles of the superficial works above described, in a considerable number of very fine promising veins.

There are several rivulets and rills of water in the neighbourhood of the mines, and good situations for reservoirs, which, if properly made use of for water engines, the mines of Iſla might become very profitable, extensive, and durable.

I beg leave to enter a caveat here against any suspicions of partiality. I never saw, nor do I know any thing in the world about the proprietor of the mines of Iſla, and I solemnly declare that any hints of information conveyed in this history shall be absolutely free, independent, and impartial, and such as I think may be useful to posterity.

I am fully convinced of the great value of the lead mines now under water in Cardiganshire, and the south-west corner of Montgomeryshire,

and, therefore, I shall hereafter give short hints concerning them, merely to point out where a treasure lies hid, which can be of no farther use to me than the pleasure of endeavouring to make it useful to others, by communicating some hints of my knowledge of it, and the hints about the mines of Iſla, and all others, of whatever kind, shall proceed from the same principles.

I know very well that a great deal of the best lead in the island of Britian lies under water, and if I can give any useful hints about so valuable a subject, I shall in so far be an useful member of society, which is an ambition I wish my mind to be possessed with.

I will now return from this digression to prosecute my account of some of the smaller branches of the mineral veins, and the next I will take notice of is a *bar*.

A *bar* is a short discontinuous vein, which runs between two parallel veins, either right across, or in a diagonal direction, and joins them both together, that is, the one end of the bar comes into one of the veins, and the other end goes into the other vein; but it does not cross either of them—it joins them together like the letter H.

A *shew* is an irregular discontinuous mineral fissure, striking out from the principal vein in an
uncertain

uncertain direction, and which generally lies in a very slanting irregular position. These imperfect mineral fissures seldom stretch out to any considerable distance from the principal veins.

A *back* is a mineral fissure, which often resembles a segment of a circle. The back breaks off from the hanging side of a vein, strikes out to a less or greater distance, fetches a sweep, and comes back into the same vein again at a distance from where it sets out.

All these inferior branches produce good ore in some mines. Ore is sometimes found in so many shapes and situations accompanying good veins, that it would be too tedious to trace it through all its various appearances, if they could all be recollected ; but as I think the enquiry of no farther consequence in this place, I will drop it at present. Some part of it will be resumed when I come to point out some other beds of the metallic ores besides regular mineral veins.

The *second* mineral vein I am to describe is the *pipe*, and the description of it will be very difficult, as the pipe at best is but an imperfect and irregular vein.

A pipe vein resembles in many respects a huge irregular cavern, pushing forward into the body of the earth in a slanting or sloping direction ; but
many

many of them with very different degrees of slope, some of them having but a few degrees of slope from the horizontal flatness, and others declining precipitately, so as to be nearer the perpendicular position than the angle forty-five. In short, they stand in all positions between the perpendicular and the horizontal. The pipe, as I hinted above, is like a huge irregular cavern, which pushes forward in a sloping direction, until it goes down out of our reach, but it is bounded by rock on all hands. The pipe in general does not cut the strata like the rake vein, but it is an opening between them, so that if the lay or position of the strata is nearly horizontal, so is the bearing of the pipe; but if the declivity of the strata is precipitate, the pipe shoots down headlong almost like a shaft. Some pipes are very wide and high, others are very low and narrow, sometimes not so large as a common mine or drift, and others again are of all the mean dimensions.

Some pipe veins are hard and others are soft. The hard pipes contain all the variety of mineral matter which is commonly found in hard rake veins. Some of them are found quite full of solid ore, others are full of ore, mixed with spar, rider, &c. and some again are full of spar or rider without any ore at all. Large pipe veins full of solid ore are generally exceeding rich.— These sometimes open out on the right and left hand

hand to a great many fathoms wide, and it frequently happens that they rise up into the roof and sink down into the sole at the same time, so that the pipe, which perhaps was not before much above a fathom high and a couple of fathoms wide, swells out suddenly into a prodigious belly, which in bearing pipes proves immensely rich ; but all the hard pipes are not of such spacious dimensions, nor do they all bulge out into such large bellies.

I saw them working a pipe in Denbighshire in Wales no wider than a good mining shaft or coal-pit. This pipe was almost round, and it put down in the rock with a slope between the angle forty-five and the perpendicular. It was quite full of good lead ore, about six feet diameter. I say diameter, because the vein or pipe was of a tubular form, and quite full of ore.

Some of the largest loughs or open caverns described above are met with in hard pipe veins, concerning which I will say no more here, as they were fully described before.

Soft pipe veins are as frequently met with as the hard ; that is such as contain soft mineral soils within the tubulous concavity of the pipe. The soft mineral soils have been described above, and therefore I need say no more about them here. The soft pipes are found in various positions as well as the hard : Some put down with a quick,
and

and others with an easy slope. The ore is found imbedded and buried among the mineral soils in the soft pipes, much in the same manner as in the wide and bellied soft rake veins, as described above, to which I refer to avoid repetition.

It should be observed, that pipe veins do not always approach the tubular form. Several of them are much wider than they are high, and these flatter pipes frequently come to be very low between the roof and sole, or upper and nether stratum, towards the skirts or extremities of the pipe upon the right and left hand. I will also observe, that all pipe veins do not continue betwixt two distinct beds of stone. Sometimes they burst their way up through the strata, and then they have a much greater slope than the ordinary declivity of the strata where they are found.

I will further observe, that in some mining fields two or more pipe veins run parallel to one another, and sometimes very near to one another. When two or more pipes run parallel to, and near one another, they are then generally flatter than a single one, and approach something near the figure and description of the streaks or flat veins, which are to come next under consideration; and it sometimes happens, that in some particular places the skirts or sides of two parallel pipes approach so near to one another, as to come in contact; and in this case, when the ore is wrought

wrought out of both, there will be a hole or communication made between them. This generally happens only when one of them flies out wider than ordinary into the side next the other.

The bearing of such pipes as continue between the strata is exactly the same as the declivity of the strata; that is to say, the bearing of such runs parallel to a line drawn across the strata from crop to dip; and it should be understood, that pipes have no horizontal bearing whatever: Their bearing is in a declining or sloping line, and is towards the same point of the compass as the declivity or dip of the strata.

I observed before, that the slope of one of these pipe veins is the same as the declivity of the strata in the mining field, and even in that part of the field where they are found; and as the declivity of the strata is extremely various, and changes so often, the slope of these pipes must be as various in different places.

With respect to the other species of pipe veins which have burst their way up through the strata, it is more difficult to point out their bearing, as they generally dip down precipitately, and may be said to have no bearing at all, as the one end dips down towards the center, and the other end points up towards the surface; and such of them as do not stand so near the perpendicular, seldom or never run in any strait line whatever, but wind
downwards

downwards in a sloping and in an oblique direction.

Some parts of this sort of pipe will sometimes put down for a few fathoms as perpendicular as a coal pit or shaft, and not unlike a clumsy round or oval shaft, both as to figure and size, and then it will turn away to one side or other with less or more slope: It is uncertain which way it will slope until we see it in working; and these pipes frequently open and contract again as we go down in them, and sometimes they will swell and belly out to an enormous wideness, and, lower down, they will contract again as narrow as ever.

This species of pipe veins are generally more irregular than those which continue between the strata; but they have this one advantage, that they are generally nearer the perpendicular position, and therefore it is easier to sink shafts in them; however, they do not all put down so near the perpendicular position; several of them have a great slope: But whether they stand nearly upright, or hang with a greater slope, they are all irregular and winding less or more, and they all contract and dilate greatly in wideness as we go down in them.

The next bed of the metallic ore that comes under consideration is the *streak*, or *flat*, or *dilated vein*, which is the third in the order set down of those I call *principal veins*. Neither this nor the
pipe

pipe can come under the denomination of mineral fissures, as in fact they are no fissures at all. The flat or dilated vein is a space or opening between two strata or beds of stone, the one of which lies above, and the other below this vein, in like manner as the roof and pavement of a stratum of coal are above and below that coal. When the strata between which this vein is found lie nearly parallel to the horizon, the vein is likewise in the same horizontal position; and when the strata vary from the horizontal position, the dilated vein varies likewise with the same degree of declivity; and this of necessary consequence, as this vein does not burst the strata, but always continues between the same two beds of stone.

These flat veins lie between the strata in some respects, as seams of coal are found; at the same time I must observe, that there is no further resemblance between them, than that they are both found between the strata, and that they have exactly the same horizontal or declining position as the strata of the place where they are found: in these respects they are to be investigated upon the same theory as the strata or seams of coal; and there is also this further resemblance, that these veins are subject or apt to be interrupted, broken, and thrown up and down by dykes, slips, and other interruptions of the regular stretch or plane position of the strata, in the same manner as in

the seams of coal, with this difference only, *viz.* that in working coal these interruptions are generally real troubles, and getting over them is so much pure loss of money and time ; whereas, on the contrary, when they are met with in working a flat vein, they often prove a great advantage, as they are, in fact, other mineral veins of different denomination and description ; so that as often as these interruptions are met with in the flat vein, it is an adventitious increase of the reality, or, at least, the chance of meeting with more treasure in the same field. In other respects, the theory of the flat vein and the seam of coal are widely different : The seam of coal preserves an equal thickness betwixt roof and pavement, and, in fact, is a stratum fully as regular as any of the strata above and below it ; whereas, on the contrary, the flat or dilated vein is only an opening or space between the strata, of very unequal depth or height, which space is always filled with mineral matter. Sometimes these flat or strata veins, as they might be called, open wide betwixt the roof and sole, or lid and sole, which openings contain a variety of mineral matter soft and hard, and generally with a lesser or greater mixture of ore ; and not unfrequently the whole space is filled with good solid ore. The flat or strata veins are frequently discovered by sinking or working downwards in the rake veins ; and when it so happens, it is reckoned

ed a lucky accident, as they can turn off, and work away horizontally in it, with the same shaft, &c. if it be found rich enough. In some mining fields they actually do work in the perpendicular, and in the horizontal or flat veins at the same time, and with the same shafts, engine, or level, &c.

These flat veins found between the strata are discovered in some mining fields in several species of stone; but they are most frequently found in limestone lying either in a horizontal or declining position.

Some English miners call the flat veins *streaks*; and when they have both a rake vein and one of these in the same field, they distinguish them by the appellations of *the vein*, and *the streak*. By the word *streak* they mean stretch, or a vein between the strata which stretches or spreads in a horizontal position. But these veins are not all found in the horizontal position: I have seen great numbers of them in a declining position, which must necessarily be the case, as these veins are always found between the strata, and are themselves in reality imperfect strata, and therefore they must of necessity have the same declivity as the strata, which is found in all degrees between the vertical and the horizontal position.

I have seen a great many of these veins in argillaceous strata of the mountain rocks, in which
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the vein itself is frequently nothing else but a soft argillaceous stratum, often containing nodules or masses of pyrites, spar, quartz, and other stones, which, upon breaking, are found to hold a less or greater quantity of lead ore; and sometimes these softish argillaceous veins contain nodules and masses of good solid ore; notwithstanding, I believe these argillaceous strata veins seldom hold so much ore as to be worth working, at least not near the surface. It is common in some places to see these argillaceous strata veins of various dimensions, from a few inches up to several yards thick; however, when the clay is strong, and of a cohesive quality, I would not advise much trial to be made in them; but if it be lax, and of a friable texture, with some ore, let them follow their own inclination.

I observed before that the flat or strata veins are not cracks, fissures, or gashes in the strata like the rake veins, but, on the contrary, they are always found between the strata, and are themselves imperfect strata, or at least each of them occupies the place of a stratum, so that there is a very wide difference in the theory of these two species of veins, the rake vein being always a longitudinal fissure, or break, across the strata in some line of direction, in which case the vein is the chasm or space between the sides of that longitudinal fracture; whereas, on the contrary, the

the streaks or flat vein in this case is a space between two layers of stone, which space is generally filled with some mineral matter or other: But notwithstanding this wide difference in the theory or natural history of these two species of veins, they frequently have a very striking likeness and agreement in their internal contents, appearance, and accidents. The flat or strata veins open and close as well as the rake veins. Sometimes the stratum, which is the immediate roof or lid of this vein, comes down and joins close to that below it, to that degree, that there is perhaps no space left between them, and little or no vestige of a vein left; and these twitches, or coming together of the roof and sole of the vein, will continue to a less or greater distance, and the vein be entirely, or in part, squeezed out from betwixt the two layers of stone, as is found in the rake veins when they check, or their sides close together. Sometimes the strata veins will continue of a moderate and pretty regular height between the roof and sole for a considerable extent, and at other times the roof and sole come together, and open again at short distances.— Sometimes the space, which we may call the concavity of the vein, is but low betwixt the roof and sole, so that when the ore is worth working, part of the roof or rock above it must be worked away with the ore, to give the workmen

room

room to advance ; and at other times they open wider or higher, so as to give room enough for a good body of ore ; and, again, they sometimes open up to an enormous height, which may be called the bellies of these veins.

The streak or dilated veins are found both hard and soft : Some of the hard streaks contain a good body of solid ore, others produce ore mixed with spar or vein-stone, rich or poor ; and some of them again are found to hold nothing but spar and vein-stone, without any ore at all. Lesser and greater bellies, with loch-holes, or open cavities, with other accidents and alterations, are found in these veins, which in many respects resemble the rake veins.

In soft streaks the ore is sometimes found in large bellies, but more frequently in flattish glebes or masses, generally lying nearer the sole than the roof. The ore in these streaks often lies in large irregular cakes upon the floor or sole, and sometimes several layers of these cakes are found one above another, quite up to the roof of a wide vein, with softness or soft mineral soil filling up the spaces between the several flattish masses.

It should be observed here, that when two or more checks or twitches in a streak or flat vein run in a parallel, and are at no great distance from one another, the streak has then a near affinity

finitly to one sort of the pipe vein ; and when the parallel twitches are near one another, and that the concavities of the veins rise to a considerable height between the twitches, they go then under the denomination of pipes, and are worked as such.

I observed above that the species of pipe which approaches in affinity to the streak, lies between the strata, and consequently it has the same declivity as the strata in like manner as the streak, so that there is an original affinity between them; and when twitches run parallel in one of these streaks, and the roof rises up to a considerable cavity between the twitches, the name *pipe* is then imposed by the miners.

The *fourth* and last capital vein I am to take notice of is the *accumulated vein*. The accumulated, concentrated, or conical vein is not easily described, so as to convey a distinct idea of it. Some of these veins approach to the form of vast irregular cones, and others of them have some resemblance of inverted cones ; but whatever is the form or description of this mineral repository, it generally contains a great deal of wealth in a small compass of ground, the accumulated veins being often the richest of all mines.

Some of these veins resemble many of the pipes,
especially

especially in their dipping down from the surface, either in a perpendicular or a slanting direction, and in their being encompassed and circumscribed on all sides with rock; but they frequently differ from the pipes in the interior structure.

The accumulated vein is often pretty narrow, or of small diameter above, and very wide at a considerable depth down from the surface, and some of them open out to an enormous width as we sink down in them; but the most remarkable distinction between the accumulated and the pipe vein, which lays most claim to our attention, is the radiated form of the accumulated or concentrated vein, from which a number of lesser veins or mineral fissures diverge every way, and stretch some of them to a less, and others to a greater distance, from the main pipe or body of the vein, in which the one end of each of them centers.

The main pipe or shaft of the accumulated vein resembles the inside of a glass-house, and the vast capacity of this vein is often stored with a rich body of metallic ore; frequently bedded with soft mineral soil; but the veins and branches which join this pipe, and diverge from it, commonly resemble our rake veins or perpendicular mineral fissures.

When the ore is worked out of a large accumulated vein, it exhibits then a horrid frightful gulph,

gulph, some of which may be fifty or sixty feet wide below, and they are often worked down to a great depth from the surface.

From some of these large pipes, a greater, and from others a lesser number of nearly perpendicular fissures, or rake veins, meet and join in one common center, from which they spread out like radii to different distances from the main body of the shaft or cone; and these branches frequently contain rich bodies of ore, which being worked out, there remains a vast perpendicular arched concavity, as it were hanging upon pillars.

We see nothing in the practice of mining so awful and tremendous as the excavations of large accumulated veins which have proved rich in ore. The mining shaft or pit for drawing up the ore, and for descending down to the works, is frequently sunk upon the vertex of the cone or perpendicular pipe; and when you descend fifty or sixty fathoms down in one of these shafts, you are then swinging in the middle of an immense void space, where you see on all sides rugged, frightful, hanging rocks, which threaten to fall upon you and crush you to pieces.

The excavations of the perpendicular irregular pipe is of itself sufficiently frightful; but when the hanging rocky sides of the main pipe or cone are slitted up and opened, perhaps from

top to bottom, in many places, in working the collateral diverging veins, the appearance of this horrible gulph is then frightful beyond description.

There is, as I hinted above, a variety of the accumulated vein, which resembles an irregular inverted cone, or the inside of a glass-house turned upside down. Some of these inverted veins are found so wide at the surface of the earth as to shew at first no appearance of a vein, as nothing is seen but a prodigious nest or heap of ore huddled together, until they go down some considerable depth, and then they find that the ore is circumscribed or encompassed by rock on all sides; and though they continue considerably wide for some time, yet they grow narrower by degrees as we go down in them, until at last they contract within the compass of one of the erect pipe veins which was described above.

I observed before that some of the pipes are very irregular at all depths,—sometimes standing nearly erect, and then turning to a flanting or a spiral position; and with respect to the capacity of this pipe, it is sometimes of middling wideness, but it often contracts and dilates again to various dimensions, and it sometimes opens out to an enormous wideness far down as well as at the surface, when it may be called an accumulated vein.

When

When a rich pipe is very wide at the surface, it may with propriety be called an accumulated vein, as there is often found in it a great body of ore as it were accumulated in one heap, and sometimes more treasure is raised out of one of these in a few weeks than can be raised out of some mines in so many years, even when they are worked with profit, and the accumulated ore is generally raised with very little trouble and cost, in comparison of the expence of working other veins.

Many iron mines are found in this description of vein, and lead and copper ores are frequently found and worked in both the sorts of accumulated veins. A rich body of lead ore was found and worked in Yorkshire a few years ago, in what I call the inverted conical vein.

I have now gone through the natural history and description of the four capital mineral veins, viz. the Rake, the Pipe, the Flat or Streek, and the Accumulated Veins, which are the principal repositories of the greatest quantities of the metallic and other mineral ores which are found within the surface of the earth.

It may be proper for me now to remark, that mineral veins are subject to several accidents which may be met with in the progress of working them; some of which are the more dangerous,

gerous, as they may occasion the entire loss of the vein, if not well understood ; and, therefore, as it is possible that these troubles or accidents are not in general sufficiently well known to all miners, they deserve to be investigated with attention.

I observed before, that the flat vein found between the strata is frequently liable to be twitched or squeezed out by the roof and sole coming together ; however, when there is no more in the case than the roof and sole coming together, they are always sure that the vein will open again, and that they will find it again upon the same level when they have cut through that squeeze or twitch.

These grips or twitches are generally pretty well understood by all miners who have been used to flat works ; but there are other troubles or accidents incident to these veins, which are not so generally known, nor so easily investigated ; such as dykes, slips, gashes or chasms, the same as are met with in the coal and coal strata, which have been described already ; nevertheless it may be necessary to touch briefly at what has been said about them. The flat strata veins, as well as the seams of coal, are subject to be interrupted and cut asunder in two by whin dykes ; by dykes of softer stone ; by dykes of imperfect indigested stone ; by all sorts of clay dykes, wet and dry,
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hard and soft, homogeneous and compound, or mixed with gingle, gravel, &c. They are also subject to be interrupted and cut asunder by gashes or chasms, which are generally filled with gingle, gravel, sand, or loose earthy matter; and all these dykes and gashes are wide or narrow, difficult or easy to get over, the same as in the coal and coal metals, which were particularly explained before. The strata or flat vein, as well as the seam of coal, will be found nearly upon the same level upon both sides of the dyke and of the gash.

These veins are also liable to be interrupted and thrown off their level by slips. When a flat or streak vein meets with a slip, it is thrown so many feet or so many fathoms up or down in the same manner as the strata of coal, where this trouble was fully explained. There is one material circumstance relating to this slip in the streak vein, which I hinted at before, and will now repeat, *viz.* that a slip in the strata is always a rake vein; a slip in the seam of coal, in any other strata, and in the streak vein, is one and the same thing in natural history; therefore, when a streak vein is thrown up and down out of its ordinary course and level by one of the rake or slip veins, if the slip happens to be tolerably wide, and to contain more or less of ore, or of other promising mineral soil, there is in that case no danger; it may rather be thought a lucky accident. They will

will follow the rake vein up or down whichever way it has thrown the streak, until they meet with it again, and then they will work one or both of them as they prove or appear worth while: But, on the contrary, if the slip or rake vein happens to be in a close twitch in that place, and that the two sides of the fracture are close and cemented together, in that case there is the more danger, as some of these slips which throw the strata and flat veins a great many fathoms up or down, are so close and imperceptible, that the flat vein may be lost without the utmost attention. Exactly the same circumstances will happen in this case in the flat vein as in the seam of coal. When the vein is cut off by the slip, and thrown off its former level, the miners meet firm stone in the face, instead of their vein, and when they touch this stone, if they are perfect in the history of the strata above and below their vein, and recognize the stone which meets them in the face, they can then make a near guess how far the vein is thrown off its former level. If it is a down slip, the vein will be cut off first above; but, on the contrary, if it be an up slip, it will be cut off first below, and there will always be some small vestige, although it should be no more than a close joint, to shew which way the vein is gone; and if they are not well versed in the history of the strata or binds, so as to know how far the flat vein is
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thrown off its former level, it may be necessary to follow the closest vife or vestigia, to prevent the danger of losing the streak or flat vein. The streak will stretch or spread out again upon the other side of a slip, much the same as it did before it was cut off by it, and as the seam of coal does. These breaks and irregularities of the strata are generally distressing troubles in the coal field ; but they do not always prove so distressing in the mining field ; very often they are quite the contrary.

I have seen ore upon one and upon both sides of a whin dyke ; and the gasches in the strata, as I hinted before, often prove very rich and fruitful veins.

The slips, which are the most numerous of all the interruptions of the regularity of the strata, are also the most frequent and the most durable mineral veins ; so that there is always, at least, the greater chance the more of these interruptions of regularity are found in a mining field ; and for a very good reason, because they are all mineral veins.

The rake veins or perpendicular fissures are frequently checked and interrupted by the sides of the vein coming close together, both in the longitudinal and perpendicular direction, and in these checks or twitches, the sides of the fissures are often so closely pressed together, that every
vestige

vestige of a mineral vein is sometimes entirely squeezed out. However, as I observed before, experienced miners are so accustomed to these twitches, that they are seldom in danger of losing the vein by them, excepting in the case of their continuing too long, there being always some dark imperfect vestige of the course of the vein remaining, though sometimes hardly perceptible, the two sides being clapped as close together as the joint between two hewn stones.

But the perpendicular fissures are subject to start aside to the right or left hand, which is sometimes a more dangerous accident than the twitch, because it is in general less known. When one of these perpendicular fissures starts aside, the miner meets solid stone in the face, and the vein is squeezed out as effectually as in the common twitch; and there is moreover this material difference between the two accidents, *viz.* When a vein is squeezed out by a twitch, there remains some vestigia of the vein keeping the same perpendicular position and longitudinal bearing as the vein, before it came into the twitch; on the contrary, when a vein is cut off by a start, or is thrown to one side, there remains not the least joint or vestige of the vein in the line of its former course, because it is started or thrown into one side quite out of its former course or bearing, and therefore it is the more necessary in this case

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to examine carefully all circumstances relating to this accident, as there are, I am persuaded, many good and valuable veins entirely lost by it.

A rake vein is thrown off its course to one side, either by a close joint, or an open cross vein.—When a vein is started, or thrown out of the line of bearing, into one side or other, it is proper to observe, that the vein in this case is always cut off by a smooth joint, which meets the miners full in the face, instead of the vein; and behind this joint, straight forward in the line of bearing, there is not the least appearance of the vein, because it is thrown off its former course to one side.

There is one circumstance relating to this back joint which deserves to be particularly remarked, viz. If the vein is started into the right hand side, the smooth joint which cut it off meets the miner first on the left hand; and, on the contrary, if the vein is thrown into the left hand side, the joint meets the miner first on the right hand, and so passes on in a slanting or diagonal direction across the forehead of the mine, or foremost working in the vein: That is to say, a perpendicular joint or close fissure throws the vein to one side in the manner now described; but if it be a horizontal joint, it comes in across the soles, and the vein is cut off horizontally, and lost entirely in the former direction as they work

downwards in it. The same rule is to be observed with respect to the horizontal start, as the perpendicular, to know into which side the vein is thrown, slipped, or started. The horizontal start or joint which cuts off the vein as they go down in it, does not cut it off in the true horizontal line, but leans or declines a little some way ; and we may be certain that the vein is gone the same way as the joint declines. I believe it may be asserted, that the horizontal start throws the vein generally into the hading or ledger side. It deserves further to be noticed, that this starting joint not only crosses the whole breadth of the vein, where it is cut off, but also continues its course forward into the side, until it comes to the vein again, to which it infallibly leads, if properly followed ; and when the vein is found again upon the other side of this start or slip, it always resumes the same position, and bears to the same point of the compass, as it did before it was lost, or thrown aside by the start. It will frequently happen in this case, that the miners will cut thro' the smooth joint which is the vestige of the start ; and for a while they may work forward into solid rock, in the line of the bearing of their vein, until they begin at last to suspect they have lost their vein. If there is a small string of ore, or a strake of good mineral soil in the joint or vise of the start where it enters the side, there is not so much danger

danger in this dilemma as if it was only a close joint, as in that case, when they are tired of working forward in clean rock, without the least appearance of recovering their vein there, they will come back to the appearance they left behind in the side, which they will better examine, and it will lead them to their vein.

But if the vestige of the start is only a close joint, without any thread of ore, &c. and they continue their mine or drift forward through it, it is a hundred to one if ever they take any further notice of it, and so the vein is for ever lost. I verily believe that many valuable rich veins are lost by this accident; for it is a certain fact, that these joints or vestigia of the start are often very close, and may be thought not worth noticing, which is my reason for being so particular on this point.

In the 2d place, when a vein starts into the side, off its former course, by the interposition or intersection of another open vein, the course and bearing of which is across the former vein, which is cut off and thrown aside, there is not much danger, as the miners will readily follow the interposing or intersecting vein, whether it bears much ore or not. It must have either ore or a quantity of mineral soil, if it be an open vein, that is, if it is a vein of any tolerable capacity or wideness, and the miners will follow the soil without
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ore in search of their lost vein, especially if it was rich. If the new vein which intersects the old one proves rich, in that case it is a lucky accident.

Having finished the natural history of the mineral veins, it now remains for me to say something about the other beds of the metallic ores, and the principal of these are two, viz. 1st, Such as are found in the heart and body of the solid rock and strata, blended and mixed with the substance and composition of the stone: And 2^d, Such as is found upon the face of the rock, which is called float ore. Gold is chiefly found in larger and smaller grains, blended with the composition of the rock; and this is the original cause of so much gold dust and grains being found in the beds of rivers. The superficies of most rocks weather and decompose, and the decomposed parts are carried down by the currents, and lodged in the beds of rivers, and the grains and particles of gold being the most ponderous, there is proportionally less of it carried forward to the borders of the ocean than of the lighter sand and gravel. It deserves to be remarked, that gold found mixed in the body and composition of the solid rock differs in quality or condition from lead or copper, &c. found blended in the rock in the same manner. In whatever place or quantity gold is found,

found, it is always found pure and malleable; whereas the other metals are generally found mineralized, that is, mixed with sulphureous, arsenical, and other heterogeneous particles, which renders them brittle and impure.

Lead, copper, and other ores are also found in the composition of the solid body of the rock in many places. I saw a stupendous rock at a place called Cwmystwith in Cardiganshire, Wales, where so much lead ore was found blended in the rocks as to be worth working and separating from the rock.

The rocks at Cwmystwith are of great height, and I saw the miners there suspended in ropes blasting down the rocks with gun-powder, and a number of busy hands breaking and knocking the compounded stone and ore small, in order to get the ore separated by washing and dressing. I believe it always happens, that where ore is found blended in the composition of the solid rock, any joints and fissures found in such rocks generally contain some ore. This was the case at Cwmystwith. They had been working some veins and strings long before I was there, and they were then going on with some of them. But it was the working away the solid rock that struck my attention most.

This part of the work was extensive, and in several places they had cut down the rock, so as to have

have very good footing for standing to work. It is so long since I saw this singular work, that I do not now remember certainly of what species or quality the rocks at Cwmystwith are; but I still retain an imperfect idea that they are limestone.

One of the most remarkable rocks containing metallic ore in the composition of the stone, is the breccia or pudding-stone at Gourock, near Greenock in Scotland.

Both lead and copper are often found in limestone quarries in several countries, and I have seen very good lead and copper in limestone in several parts of Scotland; but I do not know how it happens that few of these fine appearances in limestone have ever turned to good account in this country as yet. The copper ore found at Currie in the Lothians, and at Kiffers in the Highlands of Ross-shire, is remarkably good in quality, and trials have been made, and copper raised in both places, but not in quantity sufficient; and yet the copper at Kiffers is of the best quality, perhaps, of any ore of that metal found in Britain; and very good lead ore has been discovered in limestone, and partly wrought, near Bathgate, and also near Calder and other parts of Scotland, but not with such success as to constitute durable mines, excepting at Bathgate, where they formerly had a rich lead mine, which
yielded

yielded a considerable quantity of silver, and the mines of Isla, which are in lime-stone, which I am confident would be both durable and lucrative, if they were carried on with skill and spirit. Whether the ore in lime-stone in other parts of Scotland is really not to be found in sufficient quantity, or that the trials upon the several appearances have been made without sufficient skill, or spirit, or perseverance, I will not pretend to determine; though there is great room to suspect that this is the case, when it is so well known that many lasting and profitable mines are found in lime-stone in other countries. Mineral ores are found blended in the composition of several other species of rock besides lime-stone. The tin grains are found mixed in the composition of the granite stone in Cornwall; and I have seen lead ore mixed in the composition of the mountain rocks in the Highlands of Scotland and several other places.

There is a singular stratum of stone near Loffymouth, in the shire of Moray, of about eight feet thick, which is compounded of several species of hard and fine stones of various beautiful colours. This stratum is a species of breccia, or pudding-stone, in the composition of which there is blended in some parts of it, about an eighth part of good blue lead ore, of the species called potter's-ore.

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This curious bed of stone lies in a horizontal position, and dips away towards the north, under the sea, or Moray frith, with an easy slope, and the lead is found in larger and smaller grains and flowers blended through the whole body and composition of the stone, in the same manner as the small masses of agate, white and coloured crystals, and other species of stone are found blended through the whole body of the stratum.

I cannot help being persuaded that perfect metallic ores being found in the body and composition of regular strata of lime-stone, and in other solid rocks, is not only an argument, but a clear decisive proof, that the materials which formed the several ores, and their intermixed and concomitant spars, were poured into the veins and taken up into the composition of the strata of stone when they were first formed; and although many fanciful notions of the subsequent formation of solid ores in the cavities of mineral veins may be advanced, it is impossible to give any good reason for several species of ore being found blended with rider, spar, and stone in the cavities of such veins, and in the composition of the solid rocks which form the sides of the veins; much less can good and perfect ore, found blended in the body and composition of various strata, be rationally accounted for, without acknowledging that such ore is coeval with the strata,
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and veins in which it is found; and the float ore found in some mining fields is a farther proof of their being coeval.

Float ore is always found either spread out thin, or accumulated in hollow places upon the superficies of the rock, frequently with a bed of clay above it, and sometimes a considerable depth of gravel sand or earth above the clay. Float ore is always water worn, like stones and gravel by the sea-side or in a river. It is found like water worn bullets and gravel, of all sizes. I have seen in Flintshire rounded masses or lumps of it up to two or three hundred weight and more; and in the same float some of all sizes, down to small gravel, and part of it so small as to go through the sieve in washing, and it is always found mixed with water, round stones, and gravel of all sizes.

Now, float ore, which is so called from its being always found floating upon the face or surface of the rock, is never discovered higher nor upon a level with the vein or veins of that field, but always in lower ground near them, and it is always of the same quality, species, and grain as the ore found in the veins above, which is a clear proof that it was torn off the superficies of those veins by water, and that it was agitated in the water until all the asperities and sharp

angles were worn off, and until it settled in hollow or level places upon the surface of the rock, from whence the water could not easily lift and remove it again ; and the clay, gravel, earth, &c. were afterwards lodged above it by the future streams and agitation of the water.

I am to make it evident hereafter, that the strata, and all the phenomena of the strata, and of the superficies of the globe, were formed by the waters of the ocean raised to extraordinary high tides, and it appears to me very evident that all I have advanced about the metallic and mineral ores must have happened very early before the waters were settled in the present bed of the ocean so low as they are now found.

I am sorry that the natural history of float ore, and the methods of discovering it, are not more generally known, as I am persuaded it is to be found in many places which never have been searched, nor ever thought of. I have seen float ore in many places where no trials were ever made for mineral veins, or to know if the float was rich or not. But it may be proper for me to observe here, that there is a very material difference between float and shoad ore, although they are both found upon the surface of the rock. Shoad ore, so called by miners, is always found in loose masses of all sizes, either in or under the upper soil,

soil, sometimes upon the top, basset, or out-cropping of the vein, but more frequently a little to the lower side, where there is a declivity, and where the vein crosses the slope.

Float ore differs from the shoad in that the former is water-worn, which the latter is not; and, moreover, the float ore is generally mixed with water-worn bullets and gravel, which the shoad never is, unless it happens to be washed off the superficies of the vein by some rivulet or stream of water.

Shoad ore is a pretty sure indication of a vein where it is found, or a little above, but you must judge of the distance above, by the greater or less acclivity of the slope. If the side of the hill is very steep, it may slide a great way down; but if there is but little declivity downwards from the vein, the shoad will be found proportionally at a less distance. The shoad ore is found of all sizes, from very large masses down to the size of pease and smaller grains, and it is produced by the weathering or decomposing of the sides of the vein, so as to have the ore standing higher than the superficies of the rock, which in time slides off where the ground is sloping. It is a common thing in some mining countries for the miners to go a-shoading, that is, to go a-searching for the shoad, when they will traverse rivulets, gullies, scars, and other places where the surface of the
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ground is broken, and in some places where the superficies of the strata rise up to the grafs roots; they will even examine newly ploughed land and molehills, and not always without success. From the history or description of the float and shoad ore already given, I have no doubt that an intelligent person, though no miner, will be able to distinguish the one from the other; but in case either of them should be found, it may be proper for me to point out the proper methods which should be taken to discover the vein. Shoad ore is found in rough irregular glebes, or angular masses of all sizes, frequently coated with white upon the outside. When such happen to be discovered upon a flat level piece of ground, a cross trench should be cut to the rock in the very place where it is found, thus | ; but if you find it upon a slope, or immediately at the foot of a slope, then you are to look for the vein at a less or greater distance above, in proportion to the slope or declivity of the ground. When shoad is found upon a slope, or at the foot of it, your first business is to look about you upon all hands, to see if you can discover any other symptoms of a vein, and if not, then you must judge from circumstances what method you should chuse to discover the vein. If you find that the cover upon the superficies of the rock is thin, and the distance from the place where the shoad was found to the highest

est part of the slope is but short, you may begin a cut to the rock upon the spot where you found it, and push your trench right up the slope, keeping the surface of the rock until you discover the vein; but if you should fail to discover the vein by cutting upwards in a right line, come down again to the foot of your trench, and there cut a little across, in case the vein should run in a right line up and down parallel to your cut, or in a diagonal direction, and you have been a little to one side at first setting out. If the cover upon the superficies of the rock is thick, it will in that case be troublesome and expensive to cut a long trench, and therefore your best method is to sink a small shaft down through the cover until you come to the solids.

You must take particular notice of every thing you see in going down with this shaft, and if you find bits of ore, of spar, or of good whinstone, it is to be supposed that you are still below the vein; but if you can discover no mineral soil, nor any symptom of a vein, neither as you go down nor in the superficies of the rock, you have perhaps overshot the vein, and must come lower down, and sink another shaft about half way between the first and the place where the shoad was found; on the contrary, if you find bits of ore, or lively mineral soil, in going down with the first shaft, in that case you are to sink another still further up in the line of the first, from the place
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where the shoad was found, and if the symptoms continue stronger in the second shaft, a third, a fourth, &c. must be sunk, still keeping the line. You may happen to hit the vein in one of these pittings; but there is a chance of twenty to one against it; nevertheless, if there is either a good shew of ore, or of other mineral soils above you, the symptoms will increase in quantity as you advance nearer the vein; and therefore it is your business to continue the pittings until you either touch or overshoot the vein. When you find that you certainly are above all your symptoms, come back half way to the next shaft containing them; and if you find them again more plentiful and lively, then you should drive a drift upwards, keeping or basing the face of the rock in the sole of the drift, until you cut the vein; but if you miss the symptoms in this retrograde shaft, then you should drive the mine, as just now directed, from the bottom of the last shaft which contained them. It should be carefully noticed, if all the symptoms you once had continue or not as you advance upwards with the line of pittings. If some of them only continue, and you miss others which you had below, there is a presumption that you have overshot one vein, and that there is still another above you. In this case it is your business to advance upwards, as already directed, and to come down again to the last shaft which

which contained all the symptoms, and drive a drift from it upwards, until you cut the vein which you have overshot.

If the symptoms should appear stronger, and more in quantity, in one side of your shafts than in the other, it is probable that the vein runs up and down the slope parallel to your line of pittings. In this case you should go to the shaft which contains the most and best mineral matter, and drive across upon the face of the firm rock into the most promising side; and if the symptoms increase as you advance, push forward your drift until you cut the vein. I have already observed, that if your prospect is good, the mineral symptoms should increase as you advance nearer the vein with your line of pittings. The same observation will hold in trenching, where the cover upon the face of the rock is thin enough to admit of adopting that method of trial, which is the simplest and surest of any, where circumstances favour it. If the symptoms increase as you advance with your trench, you are sure that the vein is still before you, and must persevere while they continue; but if they appear stronger in one side of your trench than in the other, you should cut less or more across in the promising side, as circumstances encourage you, keeping the forehead of your main trench open, in order to continue it, in case you do not succeed in cutting across.

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With respect to the float ore, I do not think it safe to advise any method of trial for the vein it originally came from, until such vein is otherwise first discovered, it being very difficult to know how far the ore has been carried by the water before it was lodged in its present bed ; and, therefore, I would advise a diligent search on all hands, especially towards the higher grounds, to see if any other symptoms of a vein can be discovered before you proceed to expensive trials for it. But notwithstanding this caution in proceeding to expensive trials for the vein, it is highly proper to make trials upon the float ore itself, in order to discover what quantity there is of it, that you may be able to judge whether or not it is worth pursuing.

In trying the float ore, it is proper for you to make a trench or cut in it quite down to the surface of the rock, and to push your trench forward the way that most ore appears. It is likewise proper to push forward cross cuts from your first trench every way where any ore leads you, as there may be nests and accumulated parcels of it lodged on either hand where not expected, and, therefore, it is proper to follow every symptom, and to examine every probable spot, especially flat or hollow places.

Float ore, and likewise shoad ore, may at first be turned up by the plough, and by the spade in
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making ditches, canals, roads, &c. It may also be discovered in accidental or continued runs of water, and in any other places where the surface of the ground is broken.

Whatever way it may be discovered, it is proper to make trials upon it every way by trenching to the rock, and if the cover of clay, gravel, earth, or any other loose rubbish which lies above the float ore, should be in any place too thick for trenching, in that case you should put down pit-tings upon it here and there, and if a quantity of ore is discovered worth working, you are then to judge whether you can raise it cheapest by throwing off the cover which lies above, so as to lay the whole ore bare, or by mining it underground, and securing it over-head with timber. Whatever method is chosen, as the ore lies upon the surface of the rock, it is to be observed that there is a chance of discovering a vein in trying and raising the float ore.

Where either float or shoad ore is found in a settle or small flat spot, in the middle of a sloping piece of ground, or near the bottom of a slope, there is a very good method of trial, besides trenching and pitting, called *hushing*, which is often practised with great success; and where circumstances are favourable, it is undoubtedly the most effectual, and at the same time the most frugal method of trial in the world for making mi-

neral discoveries ; but it is necessary that several favourable circumstances concur to make hushing convenient. In the *first* place, a slope of considerable declivity is absolutely necessary ; and, in the *second* place, it is necessary that water can be collected into some convenient place for making a dam-head or reservoir for the water, and the higher up such a head can be made the better ; but the dam must be so situated that you can make little collateral diagonal cuts across the slope, on both sides, to lead or conduct the water from small rivulets or higher springs, and also rain water, into the reservoir. If a little dingle, settle, flat, or hollow place can be had for the site of this reservoir, so much the better, as the head can in that case be made with the less expence to hold much water ; but where such a convenient spot cannot be had, they are often made upon the inclining plane of the declivity, in the form of a crescent. A large dam is always better than a small one if it can be had ; and where the sloping ground to be hushed is of any considerable length from the hush-dam down to the bottom of the slope, the reservoir must contain a considerable quantity of water, otherwise its force will be spent too soon before it proves effectual to carry down the great quantity of rubbish which the water will raise in a long hush-gutter ; and, therefore,

fore, if your dam or reservoir has not a level area for the water to spread upon a considerable superficies, it is necessary that the head should be the higher, in order to make up in depth what is wanting in the length and breadth of the piece of water. I will only hint in general that the head of this reservoir and the sluice must be wide in proportion to the quantity of water to be let out at once, and to the strength of water necessary for scouring the hush gutter.

From this hush dam you draw a line right down the hill, unless there be some hillock or other obstruction by the way, in which case you must draw your line in such a direction as the water will run best in a trench or hush gutter when made. When you have worked out the line of the hush gutter all the way down to the bottom of the slope, then you must cut off the sod or upper surface of the ground out of it, about two or three feet wide, and about a foot or a foot and a half deep, all the length, to make room for it to contain a small run of water, and when the gutter is so prepared, you must let out but a small quantity or run of water at first, in proportion to the capacity of the gutter, and when the water is let out the two or three first times, the men must be divided at proper distances from one another, with their tools in their hands, to help to loosen the earth for the
water

water to carry away, and to take out obstructions which may stop the water and turn it out of the gutter. When the water is all run out, then stop up the sluice again, and turn such big stones out of the gutter as the water is not able to carry down, until the gutter is wider and deeper, and clear the gutter of all other obstructions which the water cannot remove, until it has greater weight and force than there is room for in this state of the hush. Let the water be increased every time it is let out, in proportion as the gutter wears deeper, to be capable of carrying more of it, and let the men continue to assist the water as long as the gutter is shallow, and it is safe standing upon the edges of it, which it is not when the gutter is worn so deep as to contain a strong hush of water. By only removing the big stones and other obstructions after every hush, the frequent application of the water will wear down the gutter to a great depth, generally without any digging or farther trouble than lifting and closing the sluice, and keeping the gutter in repair. When stones too large for turning out whole are discovered in the gutter while it is shallow, they must be blown in pieces with gun-powder; but when the gutter is worn deep enough to hold a strong hush or current of water, it will carry down an amazing quantity of stones and rubbish with such incredible force and

and violence, that it is impossible to describe or imagine without seeing it. The steeper the declivity, and the longer the gutter is, the greater force it has. I have seen stones of several tons weight, and as big as little huts, carried several hundred yards down a large hush gutter; and the water and stones of all sizes which the water carries down, wears at last not only the surface cover, which lies above the rock, but it also wears down, by the friction of the stones, a considerable depth of the superficies of the rock itself, and, of consequence, it must discover and wash clean all the veins, useful and curious stones, &c. which cross the line of that gutter in any direction, by which means valuable discoveries are often made; and where water can be had, and can be properly used, hushing is by far a more effectual method of trial than either trenching or pitting. When a hush is worn pretty deep, where there is a weighty cover above the superficies of the rock, sometimes great stones or other obstructions turn the water to wear the one side of the gutter more than the other; and sometimes both sides wear, undermine, and fall in alternately, until the water is spread so wide in that part of the gutter that its force is lost. In these cases it is necessary to turn the big stones to one or both sides, so as to give the water room to run as near as possible in a straight line, which

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is the only way to make it scour the bottom effectually.

But notwithstanding all I have said about turning out and removing stones in the gutter, it must only be understood that this is necessary and proper in two cases, viz. to turn the big stones at first, when they are a real obstruction before the gutter is big enough, and the stream of water strong enough to carry them down; and to turn them aside afterwards, to confine the water in the middle of the gutter. Excepting in these circumstances, the more stones the water has to carry down the better; and therefore when the hush is over, the men should be employed to loosen the stones out of the clay, to blast such of them as are too large into smaller pieces, all of which should be left in the gutter for the next hush to carry down, as the more stones come down with the water, the sooner the clay and other rubbish will be torn up and washed off, and the superficies of the rock bared and worn down. When there is a little flat, or an easy slope immediately below the sluice, and that the form of the ground will otherwise allow of it, two, or even three hush gutters may be made, and scoured with the same reservoir, by turning the water off to one side at first, and giving it a different direction, by which means more discoveries may be made, not only of other veins, but also in other parts of the veins discovered in the

the first hush gutter ; as it very often happens that the same individual vein which proves barren in one place, produces good ore in another place at some distance in the line of bearing.

This method of discovering mines by the help of water, in the manner I have pointed out, must be very effectual where the figure of the ground, and other circumstances, are convenient for this mode of trial ; and I like it the better, as it may be said to bare to the bone, and shew us every thing that is to be seen in that section of the hill.

I will now proceed to point out some of the other appearances and symptoms of mineral veins, besides that of finding float and shoad ore upon the surface of the ground.

Mineral veins may be, and frequently are, discovered in all places where the superficies of the strata and rocks are to be seen, such as upon the rocky shores of the ocean and of lakes, in rocky precipices, in the rocky banks, and beds of rivers and rivulets, in dingles or ravines, and scars, and in all other places where the solid superficies of the strata are either to be seen, or have so thin a cover that some of the mineral shoads are found mixed with the upper soil ; but where there is a thick cover of clay, sand, or other loose matter, upon the surface of the rock, all mineral symptoms are then perfectly concealed from our view, until such cover is cut through by some ditch or trench,
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or washed away by some rivulet or current of water, &c.

As a perfect knowledge of the real symptoms of mines is of material consequence, I will attempt a description of the external appearances of mineral veins, and of the several sorts of mineral fossils, which, having flidden off the surface of veins, are indications of the veins being near the place where such mineral substances are found; and if these points of investigation are made clear and distinct, men of observation may and will make useful discoveries, when traversing districts either for pleasure or business, where the superficies of the strata are to be seen. The remarks of the land-surveyor will then be more distinct and useful; and gentlemen, when searching for game through the mountains, may discover useful mines.

The rake vein, or perpendicular mineral fissure, being the most common in all countries, I will begin with it; and with respect to external appearances and symptoms, rake veins should be divided into the *hard* and the *soft*, because the indication and the contents of each are different, and will be easily distinguished.

A rake vein is a gash or fissure which cuts the rocks and strata asunder in some certain line of direction; but as the space between the sides of a vein is commonly filled up with some mineral matter or other, it requires attention to distinguish the
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back or basset of the vein from the rest of the circumjacent rocks.

Wherever the regularity of the strata is broken and interrupted, or any breach or fracture appears in the rock, there is reason to suppose that it is occasioned by a mineral vein; and therefore, when a considerable gash or crack is observed in the face of a rock, or cutting across the strata, it should be taken notice of and examined. The fissure of a vein may be distinguished from such a recent crack as is occasioned by the undermining of water, or by the gradual yielding of a precipice. The sides of an accidental recent fissure are generally rough, unequal, and jagged, and the chasm or space between the sides are generally empty, at least of mineral matter; whereas the sides of the mineral veins are more regular, and may be traced in pretty straight lines, whether the vein stands nearly perpendicular or in a slanting position, and the space between the sides, whether the vein is narrow or wide, is always filled either in whole or in part with ore, or with such other mineral fossils, hard or soft, as accompany ore in the veins.

When a hard vein is discovered in the face of a precipice, in the bed of a river or rivulet, or in any other bare rock, if no ore is immediately found in it, the first thing that should be attended to by an unskilful person is, to find the true sides of the vein, which sometimes are easily distinguished; but this

cannot always be so readily ascertained, because false sides frequently appear in the middle of a bold hard vein, by the interposition of a rider, or of other stoney matter, which apparently divides the vein into several parts. When the true sides of a vein are found, upon the outsides of which the rock or strata will again appear regular, then the contents of the vein should be carefully examined. Some hard veins contain nothing between their sides but hard mineral substances, and others contain, besides, a thin stratum or sticking of soft mineral soil, either near the middle or in one side of the vein ; and some wide veins contain more than one stratum of clay, or other soft soil. The mineral substances commonly found in hard veins are vein-stone, spar, and fluor, with the metallic and semi-metallic ores.

Lead ore, exposed to the open air in the surface of a vein, seldom exhibits its native colour and brightness, but is found either coated or tarnished ; however, when struck with a pick or a hammer, it discovers a vivid colour and shining appearance. In very hard veins the lead ore next the surface, which is exposed to the air and weather, is generally tarnished of a dun or greyish stoney hue, without exhibiting to a cursory view the least indication of any thing metallic, until it is touched with a tool or a hard stone, when its bright and sparkling texture will soon appear ; and therefore
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when a hard vein is discovered, every substance found between the sides, of whatever colour or appearance, should be carefully examined with a tool, as the ore very often does not look like itself, but appears like any other substance found in the vein, when it is either coated or tarnished.

The mineral substances commonly found in hard veins, besides the metallic and semi-metallic ores, are the vein-stones, spars, and fluors. The spars found in hard veins are of three distinct species, viz. calcareous spar, cauk spar, and quartzzy spar. The several sorts of spar are pretty easily distinguished from other common stones, being commonly of a white, a brownish, reddish, or of a yellowish white colour; and they have always a mineral appearance, and a particular structure, being either of a tissilated, rhomboidal, scaly, or of a tabulated form, in the inside of the masses, especially the lead spars. Some of the spars which are found in mineral veins are semi-transparent and others opaque; and again, some spar is tinged or tarnished on the outside of a black or brown colour; but when the particular masses are broken, they will exhibit their native texture and colour in the inside.

The vein-stone or rider has always a mishapen, irregular, mineral appearance. The purest and whitest samples of this stone have some resemblance of a burr, and it is often equal to the burr
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in hardness; but this stone is seldom or never so uniform and regular in its texture as the burrs, being frequently compounded of different species of mineral matter, such as the bases of the stone itself, which is generally of a filiceous quality, with several sorts of metallic ores, pyrites, spar, fluor, &c. blended in a hard, rugged, misshapen, heavy stone, which has the structure and appearance of a concrete, which is sometimes solid, and sometimes cavernous, and the cavities are frequently lined with druse, or clusters of transparent pointed crystals. When the vein-stone is compounded of different kinds of mineral matter, it often exhibits different colours in the same mass; but when it is mostly of one sort of matter, it is generally of an uniform colour; but whatever be its colour, it has always a rugged appearance and form, and indeed looks like a vein-stone, and not like any other stone.

The fluor or flux stone resembles some of the finest species of spar. The fluors have generally a fine glossy appearance, and they are of various beautiful colours, as white, blue, green, yellow, violet and brown, with various shades and tinges of these and other colours. They are always of a fine glass-like texture, and generally of a cubical, a rhomboidal, or of a laminated structure, and some of it is of an irregular form; but whatever is the form or colour, fluor may be known
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and distinguished by its weak and glassy constitution, and by its elegant appearance, being generally either diaphanous or semi-transparent.

When one or more of these hard mineral substances are found scattered upon the face of the ground, it may be presumed that a hard mineral vein is not far off, as these may be called the shoals and indications of the vein. When these mineral fossils are found in such plenty as to attract the attention of the observer without seeing a vein, the figure of the ground must then be considered, in order to judge of the situation of the vein which these substances come from. If the ground is pretty level, the vein may be found by digging immediately under these shoals; but if there is a declivity, the vein undoubtedly is situated higher up; and therefore, if it is judged proper to search for it, I have pointed out the proper method of trial above, when treating of the shoal ore. When any of these hard mineral substances are found in a river or in a rivulet, the vein should be found either higher up crossing the stream, or in one of the banks running parallel to the stream, because all these substances tend downwards in the course of time, by the sliding of the banks, the flow of water, and the gravity of these several bodies.

The preceding description supposes a mixture of stoney matter in the hard veins, however there
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are hard quartzzy veins in many countries, with and without ore, in which no stoney matter appears but the quartz itself. The ore in quartzzy veins is either blended in the quartz or more solid; but whether solid or mixed, lead ore in quartzzy veins is always bright and shining in the inside when broken, though it is generally dull and tarnished upon the outside when exposed to the external air.

The quartz in these hard veins is generally pretty white, of a fine glossy texture, and remarkably hard and heavy; and when any caverns are found in these veins, they are filled with prismatic crystallizations, which are so hard, fine, transparent, and pure, as sometimes to emulate the diamond itself in beauty and goodness.—

Quartzzy veins are frequently very wide and strong, with distinct sides, which may be discerned with certainty by an experienced eye, accustomed to take notice of the external appearance of mineral veins. Many quartzzy veins are so strong and bold, as to rise up in a ridge above the surface of the ground, or surrounding rocks, and be distinguished and traced in the line of bearing a great way through the mountains. I have frequently traced such veins for two or three miles in mountainous rocky countries; and it generally happens, that some ore of lead or copper is to be found in one place or other, and sometimes in several places

places in the surface of such veins ; but by reason of their excessive hardness, it seldom happens that any trials are made in these hard quartz veins, unless the ore is found at once at the surface in sufficient quantity to be worth working. But if any superficial trials should be made in some of these hard veins, they are generally attempted by unskilful workmen, who can make little or no progress in so hard a stone, which baffles all their efforts to sink down or to drive forward in it, and of consequence the work is given up, before any real and satisfactory trial is made upon the ore which appeared in it. For these reasons, most of our very hard quartz veins will remain entire, as a corps de reserve in mining, which may be of great use to future generations, when our mines which are easily worked are either exhausted, or too deep for draining out the water ; as I have no manner of doubt that there are valuable treasures in many of these veins lodged at different depths, in some near the surface, and in others further down ; and in general we are assured from experience, that the further down the better for plenty of good ore.

There is yet one sort of hard vein, the external appearance of which has not been described, and yet it is very material to be known, being frequently the most productive of all veins. The
vein

vein I mean is found in such mountain rocks as exhibit nothing but *rachel*, or a loose shattered broken rock at the surface, which falls into small angular masses of irregular figures. It is very difficult to point out the exterior symptoms of this vein where it basset out, by reason of the loose and broken state of the rock at and near the surface of the strata. Where the rocks are thus loose and broken at the surface, and fallen to small irregular masses, or mouldered down to rubbish, it requires great attention to investigate the symptoms in such ground, so as to find the basset or surface of the vein. In rocks that are thus broken down to rubbish at the surface, spar, vein-stone, and other symptoms, are sometimes scattered about pretty wide, and the more so, if the ground is any thing inclining. This debris of the broken rachel, and of the mineral symptoms thus scattered loose about the surface, is called by Cornish miners the *broil*, or the *broil of the vein*.

When veins in such rocks are not very wide at the surface, there is then no room for any considerable quantity of mineral soil, hard or soft, and therefore the mineral symptoms cannot be strong; and when the rock is fallen to loose rubbish, the mineral fissure and mineral symptoms are scattered in small strings among a number of vagrant

grant cutters, which are disjointed by the separation of the loose and broken rock, in which condition, a vein that is not very wide above is often difficult to be discovered, even by a skilful eye, and no doubt many such veins are overlooked.

However, notwithstanding these causes of obscurity, there are always some vestigia of the vein to be found, if carefully attended to; some small masses of spar or vein-stone, or some other symptoms of mineral soil scattered among the broil or in the disjointed cutters; and where such are seen they should be attended to, and some of the rachel or shattered surface of the rock should be dug off, to see how matters appear below in the solid rock, where the vein will appear distinct between regular sides, and then its value can be in some measure judged of.

The top of almost all the veins where they basset out, in some of the best mining fields, are found in this description of rock at the surface; such, for instance, as the great mining fields of Leadhills and Wanlockhead, in Scotland, where the debris of the loose and disjointed surface of the strata is of considerable depth, almost every where upon those mountains, which so conceals the basset or top of the veins, that some valuable rich veins are but lately discovered; and, in general, the basset of their richest veins is not seen, but they are discovered by cutting cross mines or galleries,

either for levels to drain the water, or for the purpose of discovery.

The soft mineral soils are as various in quality and appearance as the hard. I will make some observations upon soft veins, and describe some of the soft mineral soils; and the first I will take notice of is a white mineral soil or clay, which is sometimes fine and smooth, but often more friable and coarse to the touch, not unlike slaked lime when mixed with sand. When this soil feels a little gritty, and there is tolerable room between the sides of the vein, a little of it should be dug out and well examined, by washing it in water, and by pounding it between two smooth stones, as this species of mineral soil frequently contains small masses and grains of lead ore, which is coated white, and so of the same colour as the clay; however, by washing and pounding, some bright particles of the ore will appear, if any large grains are mixed in the soil; and if small masses of lead ore are found at the surface, by digging in a vein containing this soft soil, a plentiful crop of it may be expected below.

Red fat clay in mineral veins, which indelibly stains the hands and cloaths, indicates iron, of which I will say nothing in this place, but that the better species of iron ores are generally accompanied with red staining soft soil, by which they are easily distinguished; at the same time, it

is proper to observe, that some lead and copper veins contain a considerable quantity of iron, and consequently of a red and a brownish red staining soil; and, therefore, circumstances require to be examined with skill and care in the case of discovering soft soil in a vein of a reddish colour.

The next I shall take notice of is a bluish, a grey, a greenish, or a brown tough clay, or sticking; and when these appear in small quantity or in very thin seams between regular sides, which are nearly close together, that is, where the sides of the vein are uniformly close, with a thin vein or sticking of tough clay between them, without any appearance of ore, I would not advise much trial to be made in such veins, unless some more promising symptoms are discovered in some other places in them. But if the veins containing such soils are moderately wide, and that less or more of spar or vein-stone, &c. appears with the clay, some little trial may be made in it; but I would not go far in such trials without finding some ore.

It is proper to observe here, that mineral clays and soft soils in veins are found of all colours and appearances, which makes it almost impossible to describe them all perfectly, so as to be able to distinguish them from other common clays and soft soils; and, therefore, it is necessary, in
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the first place, to be able to ascertain with certainty that you have a vein, by seeing two sides and a regular continuous fissure cutting through the rocks in some certain line of direction ; and if you can distinctly see a fissure cutting through the strata in a continued line, and can discern two sides, and see the clay between the sides, it is mineral soil, whatever the colour and other appearances of it may be.

But it is necessary for me, before I proceed any farther, to make another explanatory remark.

I just now observed, that it is necessary to know that we have a vein before we form any judgment of such soft soils as appear like mineral soil ; and the very same may be said of the hard mineral fossils, such as spar, feldtspar, vein-stone, &c. These often appear where there is no good and regular mineral fissure or vein, and, therefore, whether the mineral fossils discovered are soft or hard, their consequence depends upon the mineral vein which they belong to. But the remark which I am going to make is this, viz. that it is not always easy to judge from the external appearance of a vein at the surface of the ground whether it is a good one or not, even where the superficies of the rock is seen, which will evidently appear from what follows. I believe I observed before that those rake veins or mineral fissures

tures which were caused by a fracture and a breach in a line, and by the fracture opening afunder to a wide chasm, without any slip or sinking down of the strata upon one side of the chasm below the other side of it, are always widest above; and that those veins which were caused or produced by a chasm and a slipping down of the strata upon one side of it, are generally narrow above and widest below.

I have so often seen very close contracted veins at the surface open out below to various capacities, that there is no room to doubt the fact, which makes the first appearance of the slip veins in some situations very deceiving, and in some circumstances not easily investigated by the most skilful, so as to enable them to form a proper judgment. Where the rocks are hard, compact, and close, or free from numberless cutters at the surface, a rake vein may be known, even where the sides of it are pretty close together; but, on the contrary, if the superficies of the strata is a rachel, or loose and shattered, and full of cutters in all directions, the investigation of a vein that is close above becomes very difficult, sometimes almost impracticable, without some trial. I have frequently seen rocks, that were solid and regular at the surface, cut by veins so narrow above, that the two sides of the vein were close together in two parallel lines, and so near to one another,
that

that to an inexperienced eye, the narrow and hardly discernible fissure would appear to be no more than a common cutter; and yet I have very frequently seen these veins open out gradually as they went down, until they became some of the boldest and widest veins below; and I am persuaded, from what I have observed in my own experience, that many rich and valuable veins are overlooked and neglected, because they are narrow and confined above, and do not look promising at first sight; and, therefore, when one of those narrow veins is discovered, with some little ore in it, supposing it is no thicker than the blade of a knife, I would advise sinking some fathoms in it, as very probably it will open out below; and if it begins to open a little at a moderate depth, there is then the greatest reason to expect that the sides will dilate to a sufficient wideness when you are deep enough down in it. But if neither ore nor spar, &c. appears at first in a regular contracted vein, then the line of bearing, or the point to which the vein trends, should be taken with an instrument or compass, and two or three trenches cut to the rock across the vein, in order to discover it at a distance, where it does not appear at the surface; as it is always found in experience that veins appear and prove better in one place than another, at the surface of the ground as well as down below,

low, and often carry ore and other mineral soils in one place, when scarcely any symptoms of the vein appear in another place, even at no great distance.

Soft mineral veins, which contain soft soils at the surface, are easily discerned and known, provided that a sufficient quantity of the vein is seen to enable the observer to determine at first sight that it is really a mineral vein and mineral soil, and not a bed of common surface clay, for these soils are not always distinguishable by the colour or by any other external appearance; and in some places, where only a little soft soil is to be seen in a scar, or other small break in the surface of the ground, neither the sides of the vein, nor any other symptom of a vein, except the clay or soft soil, are to be seen without breaking ground to make some trial, and, therefore, circumstances should be examined.

If the superficies of the rock is to be seen in other parts of the ground, not very far off, and that none of that clay or supposed mineral soil appears in those places, there is the more reason to suppose that it is the surface or basset of a vein; however, the best way to make sure work, is to dig in it to discover the sides of the vein, if there be one, and to see if you can discover any ore or other promising mineral substance in it.

But

But I should warn you here not to be too soon discouraged if you should not find the fides immediately, as some soft veins are very wide, and contain a great breadth of the soft soil at the surface; and such wide veins deserve the more attention, as they frequently prove very rich.

The soft mineral soils in veins are found of all colours and appearances, as white, black, and blackish, all the shades of grey, yellow, green, and marbled, &c.; but the most remarkable and distinguished of all the soft mineral soils, and frequently the most promising, is of a loose, light, and friable texture, often resembling rappee, and other snuff, in colour and external appearance when dry, it being sometimes blackish, but generally brown, in all the degrees and shades of that colour.

When veins are regularly open and roomy between the fides, or open into irregular bellies and large cavities, containing considerable quantities of this brownish friable mineral soil, it is generally looked upon by miners as a promising symptom. But it is proper to remark that the most promising symptoms in mining often prove fallacious and uncertain. The same mineral substances, or mineral soils, hard and soft, that accompany good ore in some places, will be found in good and regular veins in other places, and yet no ore discovered, or none to signify, by the
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most judicious trials, so that ore is the best, indeed the necessary symptom of a good mine.

Good ore may be, and often is, discovered by digging in a barren vein with promising symptoms; but if no ore was ever found in the field, I do not hold it wisdom to proceed too far in trials without finding some of it. At the same time it must be acknowledged, that this soft mineral soil, which miners call *chun*, *ghurr*, or *mother*, is the most promising, and is often found in great quantities in the best mines of lead and copper. In some good mining fields, where the veins are wide and roomy, and produce plenty of ore, it is not uncommon to find great quantities of masses of solid ore of various sizes lying loose in this sort of soft soil; and in some places where the concavities of the veins are exceeding wide, there will sometimes be found a single mass of solid lead ore so large as to produce a great many tons of lead.

Where these soft soils, or the hard broil of spar, vein-stone, and other symptoms of a mineral vein, are in such quantity, and of so good a quality, as to induce you to look into the vein, and you cannot readily discover the sides to direct you to sink a little in it with propriety, your best method in such a case is to cut a trench upon the place down to the rock, in the form of a cross, as directed above in the case of finding

shoad ore upon level ground, which is the surest method of finding the sides and course of the vein; and when you have discovered these points, you will then be able to judge how you should proceed.

It has been observed that mineral veins may be discovered in almost all places where the upper surface of the ground is so broken as to discover the superficies of the strata, such as in the rocky mountains and cliffs, in the rocky banks and beds of rivers and rivulets, in ravines or gullies, and in all other places where the surface of the rock is to be seen.

Generally all the large caverns and smaller cavities upon the shores of the ocean are mineral veins. These veins, and the mineral soils contained in them, are much softer than the rocks which are cut by the veins; and being continually exposed to all the changes of the air and weather, and more especially to the rage of a stormy ocean, whose mighty waves dash against the shores with a force and fury that is almost irresistible by the hardest rocks, the mineral soils are worn out of the veins.

When a vein points in any direction into the sea, the continual beating of the waves against it wears the mineral soil out of it by degrees, and then it becomes an empty cavern. These excavated cavernous veins are very numerous, almost

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all round the sea coasts of Scotland, many of which I have entered and examined with lights, and I have seen both lead and copper in numbers of them, many of which are very deserving of attention.

Some celebrated writers of natural history have asserted that mines and mineral fissures are only to be found in mountains and hilly countries, and that there are none of them in the plains and valleys, which is an erroneous position, absolutely false in fact and in experience. I have myself seen great numbers of veins upon the shores of the ocean, where the ocean was the boundary of extensive plains. I have also frequently seen them in the beds of rivers, in places where the surface of the rock was washed; and I have often seen both lead and copper in them. I have seen very considerable mine-works carried on with success so low as in the beds of rivers, which were turned into new channels for that purpose, in North Wales, and in other places, which rivers were but a little elevated above the level of the sea. These instances are sufficient to prove the fact, and there is no arguing against observation and experience in such cases.

And, moreover, agreeable to sacred philosophy, in the investigation of the phenomena of the strata, there are the same natural reasons for the existence of veins, and even of their great numbers,

numbers, in the plains as in the mountains. I will just now defer the tracing out and explanation of these phenomena; they will come in my way in some future enquiries in the third part of this work; at present, I will only observe, that the position is dangerous as well as false, which is my reason for insisting upon this topick. If it is once received as an undoubted fact, that no mines nor mineral fissures are to be found in plains and valleys, farewell to any enquiries about symptoms or attention to them. Upon this supposition, if good shoad ore was found in a plain, the reasoning mind would immediately suggest, that it was carried and dropt there by accident, and of course it would be overlooked, neglected, and forgotten.

Wherever the superficies of the strata are discovered in low plains, we see them as frequently cut by mineral fissures, as in the mountains; and oftentimes the veins are more numerous in the plains than in many very hard and lofty mountains; and as ore is seen in veins, and worked in such low places, and as veins are seen as numerous in the rocky shores of the ocean, and running under the sea, as in many other situations, there is no room to doubt that mineral fissures, containing all sorts of mineral ores, exist in the low plains as well as in the hills and mountains; only the situation is not so favourable for discovery.

ry, the superficies of the strata being frequently covered in the plains by earth, sand, clay, and gravel.

But it may be observed here, that some plains are composed of strata in which metals or mineral ores are seldom found; such for instance are beds of chalk, of schistus, and of the coal metals. Metallic ores are but seldom found in any of these: I do not say never, as all the slips and dykes in the coal fields are really mineral veins; and I have seen some little lead and copper ore in some of them; and a valuable lead mine has been worked a long time at Coalcleugh in Northumberland, which, as I was told, is entirely in the coal metals, that is, in such strata as accompany coal: And moreover I was informed, that the lead vein at Coalcleugh actually cut off the stratum of coal, in the same manner as it is cut off by a common coal-dyke; and that the coal was found to floor and stretch upon the other side of the vein of lead, as regularly as before it was cut off by it. However, this is an uncommon instance. In general we know by experience, that free-stones, argillaceous tills, and the other concomitants of coal, are unfriendly to the metallic ores. I have not seen, nor heard of any metallic ores being found in chalk; and although I have seen ore, in small discontinued quantities, in schistus, I never expect to see a plentiful and durable mine in it.

It

It may be objected to this, that the iron-stone so frequently found in thin strata, and in nodules in coal fields, is a refutation of what I have advanced, as this iron is found in such abundance among the coal metals in many places, as to become the foundation of increasing manufactories in many places which employ thousands of hands; but it must be remembered, that this is iron-stone, not iron ore. This stone, it is true, is found in great plenty in many coal works, and in the near neighbourhood of them; but it is as seldom found in the mineral fissures, that is, in the dykes, slips, gashes, in any considerable quantity, as any other of the metallic ores. This iron-stone is found in regular strata and in nodules, which have been broken off from the superficies of the strata, rolled in water, and afterwards lodged in the argillaceous strata of the coal fields; and as this species of iron-stone so frequently accompanies coal, and is always found in the same circumstances of strata and nodules or glebes, it must be reckoned as one of the coal metals, or concomitants of coal. Iron ore, properly so called, is found in mineral veins, in the same manner as lead and copper, &c.

The strata which are generally the most productive of the metallic ores are limestones. Most species of whinstones, or the indurated argillaceous mountain rocks, of which there are many varieties

rieties, appearing in thick, thin, and middling strata, and some of these rocks are very hard, and others of middling hardness. These mountain rocks are of various colours, though mostly of some of the shades of grey. Many rich and valuable mines are found and worked in granite or moor-stone rocks: Such, for instance, are the lead mines of Strontian, in the Highlands of Scotland, and several mines in Cornwall, &c. These three orders or classes of rocks and strata are most commonly cut and intersected by mineral fissures, containing the greatest quantities of the metallic and other mineral ores.

In many countries, such as Derbyshire in England, the island of Isla in Scotland, &c. limestone is the most common repository of the precious and useful metals. In other countries, the most productive veins are found in granite rocks, as at Strontian above mentioned, where many of the veins are remarkably strong, bold, and roomy, in which exceeding good lead ore has been found in great quantities, and, in my opinion, few mining fields in Scotland promise better success, if the best veins were properly explored with skill and perseverance. But this valuable mining field has always been very unlucky. It was first opened by the York-Building Company, when the ore was exceeding good and plentiful; but in whose management, or rather mismanagement,
nothing

nothing could prosper, and ever since they failed, these mines have always been in the hands of such as either wanted skill, attention, or prudent able management.

But of all the classes of strata in which productive mineral veins abound, the indurated argillaceous mountain rocks are the most numerous and extensive. In Britain, all the rich and extensive mines of Leadhills and Wanlockhead, the mines of Tyndrum in the Highlands, of Machrimore in Galloway, and many others in Scotland, are found in some one or other of the species of this rock. Many of the mines of North-Wales, almost all the numerous, rich, and extensive mines of Cardiganshire, and most of the other mines of South Wales, are in these strata, and so likewise are great numbers of the mines of Yorkshire, Westmoreland, and many parts of the North and South of England.

I should in this place take some notice of the indications and external appearances of pipes and streaks, that is, of the pipe and flat veins. As the pipe veins only push downwards in a slanting direction, like an irregular pit or shaft, we are not to expect to find any longitudinal stretch or course in the external appearances of this sort of vein. This vein only bassets, or appears at the surface in a confined spot of only two or three feet, or of two or three yards diameter, and therefore we need

need not look for the indications at any considerable distance from that confined spot, only when the basset or outburst of the pipe is situated upon a slope, or that the ground has been much stirred by ploughing or otherwise, the mineral symptoms, whether hard or soft, may be scattered about much wider than the real diameter or compass of the basset of the vein, when it enters within the solid superficies of the strata. If the basset of the pipe is situated upon a slope, the mineral symptoms will tend downwards, and therefore the basset of the vein where it enters the solid strata must be looked for higher up than where the symptoms are found ; but if the site is upon level ground, the mouth of the pipe should be found about the center of the mineral symptoms which appear, unless there is good reason to suppose that the shoals or indications have been all moved one way by some natural or artificial cause. The mineral symptoms or foils of the pipe are the same in quality as those of the rake, which have been described.

The external symptoms and basset of the streak or flat dilated vein, has a longitudinal stretch or bearing as well as the rake vein. I have before noted and described this species of mineral vein, as being situated between the beds of particular strata, one particular stratum of the rock being the roof or upper side, and the next stratum below being the

sole or under side of this species of vein; and this vein doth not cut in any direction across the strata, but, on the contrary, it stretches horizontally between the strata, and therefore it has exactly the same longitudinal bearing, and the same spread or stretch every way, as the strata of the field in which the vein is found; and the flat vein is subject to all the accidents and irregularities of these strata, such as being thrown up and down off the ordinary level, stretch, and bearing of the strata, by slips and hitches, and of being partially cut off by dykes and gashes, which were described in the first part of this work. But it may be observed, that miners have one consolation in meeting with these interruptions of regularity, which colliers are not favoured with, viz. every one of these are mineral veins of another description. The parallel, direct, and oblique slips, which throw the strata and dilated vein up or down off its former stretch and level, are each of them rake veins, and therefore, in meeting one of these in the course of working the dilated vein, a new chance of additional treasure presents itself to them, without their being at any trouble or expence in looking for it. When a slip or rake vein is discovered in the progress of working a flat vein, it very often happens, that the slip vein contains good ore immediately when first touched, and in working this ore out of the slip vein, they come at the flat vein; where

where it floors and spreads out again upon the other side of the slip, whether it was thrown up or down by it.

The theory of the slip will, I hope, be now so well understood by my readers, as to enable them readily to comprehend, that when a miner is working forward in a flat vein upon one side of a slip, with his face towards one perpendicular point of the compass, and meets a down slip, if he was working upon the other side, with his face towards the opposite point of the compass, it would from thence be an up slip. The streak, flat, or dilated vein (for it is known among miners by all the three names) is frequently discovered by working downwards in the perpendicular mineral fissure, or slip vein. The flat vein appears in one or other of the sides as they go down in the perpendicular vein, and sometimes it contains ore immediately when discovered, and sometimes none at all, or very little of it. When good ore of sufficient workable thickness appears immediately, there is no difficulty or cause of dilemma in the way. In that case they work away horizontally in good ore in the flat vein; but in some mining fields, the flat veins are overlooked, when they only contain mineral soils without ore, or a small quantity of ore where first discovered, which perhaps is not immediately worth working, because the miners in some countries do not understand

derstand the dilated flat veins, and therefore are neither moved by curiosity nor hope to look into them. I have, in some mining fields, seen five or six inches of good lead ore overlooked and passed by in working downwards in rake veins, without making the least trial upon the ore, particularly in the island of Isla, where I could not engage proper attention to the flat veins, because the miners knew nothing about them; and as my visit there was but short, I had no opportunity of making them understand this species of vein. However, in Derbyshire and other parts of England, great attention is paid to all the streak veins. Indeed, much of the treasure of some mining fields, such as Derbyshire, is found in the streak veins; of course there is no danger of their being overlooked, whether rich or poor, for they know very well by long experience, that this description of vein is fully as subject to checks and twitches, and other interruptions of regularity, as the perpendicular veins. It is very common for the flat vein to be squeezed thin upon one side or other of the perpendicular vein; and, therefore, in a productive field, the flat vein should always be tried some fathoms in from the slip vein, until they are past the influence of that squeeze or twitch.

It was observed that dilated veins are most commonly found in the lime-stone country, that is, where strata of lime-stone are the prevailing rocks;

rocks ; however, they are not excluded from the halle-whin and some other classes of strata.— Whenever perpendicular fissures appear in the strata of lime-stone, there is always a chance, almost a certainty of meeting with streaks, if the perpendicular veins are worked to any considerable depth. When the superficies of the rocks are bare and exposed to view, where a flat vein basset out, the indications of the vein or the mineral soils, whether hard or soft, which belong to the basset of the vein, advance forward along the surface of the ground, in the same longitudinal line as the bearing of the strata ; and, therefore, when any part of the basset or outbursting of a streak is discovered, if the trending of the strata in that place is known, the proper method of trying the basset of the vein in different places is easy and simple, as this vein always continues between the two particular strata which are at first found immediately above and below the vein.

Where the basset or superficies of a streak is discovered, and you want to make some trial to see how it appears under cover, at some considerable depth or distance from the surface of the earth, you are not to expect that this vein is to dip down precipitately like the perpendicular fissure, unless the dip or declivity of the strata in that place is so precipitate as to stand near the
vertical

vertical position. In trying this vein you must consider the disposition of the strata. If they are so flat as to approach the horizontal position, so will the vein ; and, on the contrary, if the strata hang with so great a slope as to be near the vertical position, the vein will dip with just as great a degree of slope, and, likewise, in all degrees of medium slopes between the vertical and horizontal positions ; and, therefore, when the position of the strata is known, you know exactly how to pursue a streak under cover, even with unskilful men ; and where there is not a considerable body of ore, or of other good soils, to be an infallible clue to lead them in a right direction.

I will now give some account of the appearance of the metallic ores, as they are found in the basket of the veins when first discovered at the surface, or lying loose near them.

I have before described what is called shoad ore of lead. By shoad ore is meant lumps, masses, or grains of ore which have either slid off from the basket of a vein, which is situated upon a declivity, or else lie loose upon the back or basket of the vein, and that is carried down by a stream of water.

Having before treated of the shoad ore, I will only repeat here that the shoad of lead is always either coated or tarnished, unless it has been recently

cently broken and bruised by some accident, so as to discover its native colour and brightness. Shoad lead ore found in a dry situation, or any way blended with or buried in the soil, is generally coated over with a white crust, or ceruss, resembling lime, which perfectly conceals the bright blue colour of the ore until the mass is broken ; but shoad found in a rivulet, or in any run of water, is generally tarnished, of a dull greyish leaden hue, at first sight no more goodly nor attracting to the eye than common pebbles found along with it in the rivulet.

Lead ore found in the basset or surface of a vein, either in hard or soft mineral soil, seldom exhibits any of its native colour and brightness, but is either tarnished or coated. Such masses and grains as are found in the soft soils in the basset of soft veins, are generally coated white, though they are also coated of a brownish and of a yellow colour in some soft veins. In the basset of hard veins, the lead ore which is exposed to the air and weather, is most commonly tarnished, of a dun or greyish stony hue, without exhibiting to a cursory view the least indication of any thing metallic, until it is touched with a tool or a hard stone, when its fine texture and bright colour will appear ; and, therefore, when a hard vein is discovered, every substance found between the sides, of whatever apparent colour, should

should be carefully examined with a tool, as ore in such a situation does not look like itself, but appears at first sight like any other indifferent stony substance, when it is either coated or tarnished, but when broken, the colour and texture will appear, of whatever species it may be.

There are three principal species of lead ore, which are easily distinguished from one another, viz. *cubical potter's ore*, the *fibrous*, or *longish-grained ores*, and the *granulated*, or *steel ore*, and of these three there are many varieties.

1st, What is commonly called *potter's ore*, on account of its being used for glazing earthen ware, is found in greatest quantity of all the lead ores. Much of this species of ore is of a tessellated, cubical, or diced structure. Some of the varieties of this species of ore are composed of very small cubes, others of middle-sized, and some of pretty large cubes, even up to near an inch square, the cubes appearing of a laminated texture, and slightly adhering together, so as to be easily broken to pieces with a small blow, and when broken, the ore appears very bright and glittering, and of a fine metallic blue colour.

Many of the varieties of this species of ore appear of a laminated and of a scaly structure, approaching to, but not of a regularly diced form; and of these some are composed of large broad scales. And again, some of these laminated or
scaly

scaly ores have no appearance of a cubical form, but the masses of ore appear partly of a convoluted structure, the scales being irregularly disposed and placed all manner of ways.

But it may be observed of the potter's ores, that in general a rich and plentiful vein produces ore of a regularly diced form, without much variety of structure; but when the vein is confined or irregular, or any way disturbed by checks, thick riders, or from any bending or warping of the vein, the ore which it produces is generally found of an irregular texture; and if the vein is much contracted and irregular, the small quantity of ore which it yields will be found in misshapen masses of a tortuous, imperfect, scaly texture. However, when the veins are freed from these accidental irregularities, and open into wide concavities, producing rich bodies of ore, the ore will then assume a regular form and texture.

All the potter's ores are extremely heavy, and they commonly yield a great produce of lead in smelting, but they seldom contain much silver.

2d, The fibrous lead ores. These frequently exhibit a longish grain or structure, sometimes approaching a striated form or texture, but not perfectly striated, and very difficult to be described. I have seen some of the varieties of this species exceeding bright and beautiful, and more of a whitish blue, or a silver colour, than the

bright potter's ores, and many of them are remarkably rich in silver.

3d, The steel ore, or steel grained lead ore, is of an uniform and granulated texture, some of the varieties of which are composed of fine grains, appearing in the inside of the mass like fine steel when newly broken; some like coarser steel, and others appear like coarse iron. Much of the steel grained lead ore is bright and sparkling in the inside of the masses, and of a fine blue or silver grey colour. Some of the varieties are of an iron grey, and others still more dull in the inside, and approach to a blackish grey.

The steel ores are mostly very hard, the masses being frequently sonorous in some mine works, and they are generally rich in silver.

There are rich and durable mines of this species of ore in Cardiganshire in Wales, and many other parts of Britain. Many of the veins producing this sort of ore in Cardiganshire contain strong, regular, and extensive ribs of solid ore, some of which I have seen working to great advantage; but several of these rich and valuable mines are now under water.

Cardiganshire is one of the most rich and extensive mining fields in Britain.

A great many veins in the neighbourhood of Darenvaur, Cwmsymlog, Cumystwith, about the north and north-west corners of the country, and
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in many other places, have produced great quantities of the richest lead ore in the island, at least the richest in silver. Many of these veins were opened and worked by the Romans, whose works were remarkable and singular, being all open cast, like a great ditch or gulph. They cut open the vein longitudinally, and formed wide gulphs in the course or bearing of the veins. I saw one of these gulphs at Darenvaur, where the fine steel ore was very rich in silver, so large, deep, and long as to begin upon one side, and reach quite through the summit of a considerable mountain; and this vast trench was so deep and wide as to be about seventy fathoms down below the surface of the ground near the summit of the mountain; but they had worked none in the vein down in the level ground at the foot of the mountain, where I saw very rich modern works under level, upon a regular rib of steel ore, which was from a foot and a half to three feet wide in different parts of the vein, and remarkably rich in silver.

Great numbers of these veins have been worked in modern times, as deep as they could go, with such level mines as were easily obtained to drain the water; but as Cardiganshire is distant from the wealthy mining countries and mining companies, little or nothing to signify was done below level about forty years ago, when I was pretty well informed of the mineral history of that

that county ; and I was lately told that very little has been done below since that period.

When these rich veins are opened again, and well explored, valuable treasures will be found in most of the old soles below the levels, by which they were formerly worked, as well as new ground, in different places in the course or bearing of those veins.

I have myself seen fine ribs of solid ore in that county from one to three feet thick and upwards, which are now lying under water ; and I was then well informed of others which I did not see. Few of these rich mines can now be effectually opened without some powerful machinery for drawing out the water.

As most of Cardiganshire is a hilly country, consisting rather of ridges of a moderate height, with narrow valleys between them, than of high mountains, rivulets and runs of water may be collected and led to proper places, and reservoirs may be made for keeping quantities of rain water, for working powerful hydraulic machines in many places. In other situations, nothing would answer effectually excepting the steam engine ; but there is as yet no pit coal discovered in that county, nor near it, and the expence of bringing coals by sea, with the addition of duty and a long land carriage, cannot be supported by any common produce.

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The country to the northward, north-east, and eastward of Darenvaur, abounds in peat bogs, and some veins bearing lead ore have been discovered, but not explored in the middle of some of these peat mosses. Where good ore is found, and water cannot be had, or cannot be properly applied, steam engines may be worked with good peats well prepared. In preparing peats for the engine, the upper parts of the moss must be cut off and thrown into the old peat pits, where it will vegetate again, and ensure the duration of the moss; and nothing but the black heavy peat should be prepared for use. This black moss must be cut into small peats, and the cutting should begin early in the spring, in order to have the peats in good condition before the heavy rains come on, the dry weather of summer in that country being only in the months of March, April, May, and sometimes June. The heavy black peat, which is of a close and solid substance, cannot be thoroughly and perfectly dried in one year; but when two years old, and well prepared, well thatched, or kept under a shade, they make a strong, clear, and durable fire, little inferior to good coals, and even better than such as are but indifferent. Steam engines may be effectually worked with the black peat, without any material alteration in the construction of the machine, excepting that the furnace may be a little wider than for pit coals. Mess.

Taylor

Taylor and Symington's new improved patent engine will answer best for such mining countries as Cardiganshire, because it certainly can be worked with much less fuel than any other engine that has yet appeared.

Besides the above-mentioned blue lead ores, there are other species of different colours, such as white, yellow, green, brown, and a yellowish brown colour, &c. But these several species are scarce, and of little consequence, as they are but seldom found in such quantities as to constitute rich veins worth working, and therefore a particular description of them would be as useless as it is difficult.

These several sorts of lead ore can only be distinguished from other mineral substances by a skilful eye, and even the most experienced are not always certain of them without proper trials.

Copper ores are found in Britain of almost all the colours on earth and shades in the rainbow, such as black, red, brown, yellow, green, blue, grey, with all the mixtures, shades, and tinges of these colours, and the ores of copper assuming such a great variety of colours and appearances makes many of them difficult to be known, as some of these ores resemble at first sight a great many other fossil substances. However, all the copper ores are not so difficult to be known; many of them

them have a bright metallic appearance in the inside of the masses; and it may be observed of most of these ores, that they have always a mineral appearance which will distinguish them; and when masses or shoals are found which are doubtful, there is a short and ready way of trying this metal, to know with certainty whether the doubtful mass contains any copper or not, viz. Put a little aquafortis with a feather upon the mineral mass; let it act upon it for a minute or less, and then touch the part with a knife, a key, or any other polished iron, and, if it is copper ore, a thin plate or scale of pure copper in its native colour will appear upon the iron. The aquafortis dissolves part of the copper out of the ore or stoney mass in which it is concealed; but when the iron comes in contact, it imbibes the acid, which leaves the copper behind upon the surface of the iron. But it should be remarked, that if the copper is mixed with, or contained in any species of gypsum, vitriolic pyrites, or other mineral substance, containing much of the vitriolic acid, the aquafortis will not act upon the copper so as to produce the real metal in this experiment. In this case, fire is necessary to prove the existence of copper in the doubtful samples.

There are a great many species and varieties of copper ore found and worked in this island, some of which I will describe in a plain and familiar way,

way, so as to convey a distinct idea of the several sorts when discovered. Some species of copper ore are of one uniform colour, and other species contain two or more colours in the same mass of ore :

1st. Native copper, commonly called virgin copper, resembles the real metal itself in colour and quality, as it may be either cut or hammered when first discovered or dug out of the earth.

2^d. Grey copper ore is a common species found in Britain. Some of the grey ores are of a granulated texture, or steel-grained, tolerably bright in the inside, considerably ponderous, and of a silver grey, a stone grey, or of an iron grey colour. But all the grey copper ores are not of a granulated structure ; some of them are smooth and uniform in the inside, and when the ore is bright, it exhibits a glossy appearance, and this sort is frequently called glass copper, or vitreous copper ore. Many varieties of the vitreous ores of this colour discover less or more of a yellow or of a brown mixture with grey, when you look attentively at the inside of the masses ; and again all the varieties of the grey ores are not of a bright metallic appearance, some of them being more dull and tarnished. This species commonly yields a good produce in smelting, and some of the varieties are often found to be rich in silver.

3^d.

3d. Red copper ore. Some varieties of this species are of a clear bright red, and of a smooth uniform texture, called vitreous red copper ore; but the most common sorts are of a darker red, approaching to a brownish red colour.

The masses of this kind are sometimes sonorous, generally ponderous, and some of the varieties are more like the melted metal than any other species of mineralized copper ore. Some of the red copper ores are of a granulated, and others of a solid uniform texture. The varieties which are of the finest red colours are generally bright and glossy in the inside; but some of those which are of a brownish red, have a more dull and ordinary appearance; however, most of the red ores yield a good produce in smelting.

4th. Yellow copper ore is the most common species found in Britain. There are a great many varieties of yellow copper ore, most of which are very bright and beautiful, of a glossy metallic appearance, and of the colour of polished brass. Some of the best of the yellow copper ores approach to a laminated texture, and are smooth and shining in the inside. Some of the yellow copper ores are of a granulated or steel-grained texture, but most of the varieties are smooth and uniform in the inside, without any determinate grain. Many of the yellow copper ores differ but little in appearance from some of the brighter

pyrites; it requires a skilful eye to distinguish the one from the other, and sometimes they cannot be distinguished without aquafortis, or some other mode of trial. But although yellow copper ore is the most common and the most beautiful, yet in general it is not the richest. Most of the varieties are the poorest in the produce of the furnace; but what they want in quality is made up in quantity, there being more rich and plentiful mines of this species in Britain than of any other colour.

When yellow copper ore exhibits a tinge or efflorescence of green, it may generally be known as such by the young miner; but when it is of an unmixed yellow colour, it should be tried with aquafortis or otherwise, before the landed gentleman builds too much upon its value.

5th. Copper ore of a mixed colour, containing two or more colours in the same mass of ore. In some veins masses of copper ore are found of a pure unmixed green colour, and also of a blue colour. Some masses are purple, and others black, and of a liver brown colour, with little or no mixture of other colours in the respective masses; but it more commonly happens that several of these colours are blended with yellow, and may be distinctly seen in the same individual mass of ore. Masses of copper ore, or of supposed copper ore, of a pure unmixed green, blue, purple
or

or liver brown colour, and of a smooth uniform texture, require to be tried with aquafortis, as well as the pyritical or marcafical yellow copper ores, before it is determined that they really are copper; because very many stones and pyrites so nearly resemble these in colour, texture, and the general appearance of the mass, that sometimes they cannot be certainly distinguished without trial; however, the doubt is soon cleared up with a drop of aquafortis, and a key or knife, as directed above, excepting in the case of the mass of ore being mixed with a gypseous matter, or being saturated with the vitriolic acid, in which case the aquafortis will not dissolve the copper so as to produce a thin plate of it upon the polished iron; and therefore, when the mass of ore has a strong metallic or mineral appearance, and yields no copper with the aquafortis, it will be prudent to have it tried by a proper chemical process.

The copper in many veins is composed of yellow and green; in other veins the ore is chiefly of the yellow and brown colours blended together. In some veins we find a mixture of yellow, brown, and green; in others a mixture of yellow, black, and brown; and in some veins there is a mixture of yellow, purple, and of all the glowing colours of the rainbow and peacock's tail. In short, copper ores are found of all colours, and of all the shades and tinges of those colours, and many of
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those colours are often mixed and blended in the same vein, and several of them even in the same individual mass of ore, which makes a just and proper description of some of the copper ores a difficult task.

Some of these mixed copper ores are of a granulated texture, or approach to a steel grain ; but most of the varieties are solid, hard, and firm, and of an uniform texture. Some of these are dull and strong like, and many of them appear of various degrees of beauty and metallic brightness.

Copper ore is often decomposed and dissolved by corroding waters passing over it ; and the particles thus dissolved are often carried away by water, and lodged at different distances from the veins. This weathered or dissolved copper is found in many places in the state of an ochre or of a loose powder.

This powder is commonly of a green or of a blue colour, and is called mountain green and mountain blue, some of which appear of a beautiful bright green and blue colour, and others are of a more dull and earthy appearance. Some of the ochreous copper ores are indurated, and others are more loose and friable ; however all these may soon be ascertained with a little aquafortis. In this experiment, the friable ochreous and the powdery samples must be put into a drinking

drinking glass, with some aquafortis, and after standing about a minute, touch the liquid with a key or a knife, and a thin plate of real copper will appear on the iron, if the matter so tried contains that metal.

Copper found in the state of an ochre or of a powder is commonly mixed with calcareous matter, and effervesces in the aquafortis, in the same manner as lime-stone and other calcareous substances, and some copper ore found in veins likewise effervesces with aquafortis; but the calcareous mixture does not hinder any of these samples to shew the copper upon the iron in the experiment with aquafortis.

The several sorts of copper ore cursorily pointed at under these few heads, especially the last article, might be sub-divided into a number of distinct species and varieties; but as my whole aim is to point out such descriptive marks and characters as shall make these ores known, and as may distinguish them from other fossil bodies of nearly the same colours and appearance, I am no way concerned about a formal regular mode of classing them. I only wish to make them known.

The mineral veins which contain the various species of copper ore, are exactly of the same description as the lead veins, and the various un-metallic mineral substances, hard and soft, contained

tained in those veins, are the same which have been fully described above, and, therefore, a farther repetition would be useless. However, it may be observed, that in soft veins containing chun and mineral clays, we need not look for copper in the white and whitish friable clay described above, which frequently contains particles, and sometimes small masses of lead ore coated with cerufs. There seems to be a quantity of native cerufs mixed with this mineral soil, which perhaps has been produced by acid corroding waters dissolving part of the lead ore, which produces the native cerufs that is mixed with this clay, and which coats or covers all the shoads, and all other masses of lead ore that are covered with a white coat, efflorescence, or rust.

The veins which contain copper and lead ores, as I observed above, are the same, and the various mineral bodies which accompany both these ores are also very near the same, and to save unnecessary repetition, it is also proper to observe, that the various kinds of copper ore are found in hard and soft veins, exactly in the same manner as the various species of lead ore; and, therefore, when a mineral vein is discovered, in which no lead ore is found, it should be carefully examined for copper.

As all mineral substances in the basset, outburst, or surface of a hard vein are sometimes so
tarnished

tarnished and discoloured as to conceal their native hue and appearance, I before advised that the surface of every substance within the sides of a hard vein should be broken or scratched with a pick, or other iron tool, and if no lead, or but a very small quantity, is found in it, it should then be carefully examined for copper. Copper ore in a hard vein may be either red, black, blue, green, yellow, grey, and brown, or of the various shades and various mixtures of these colours.— Most of the copper ores of the simple colours, and of their shades and varieties, have a mineral and metallic appearance, with various degrees of mixtures, sufficient to distinguish them from mere stones or other mineral substances of the same colour, especially in very hard veins. However, some varieties of these ores may be so dull and tarnished as not to be easily distinguished, in which case, aquafortis should be used, when fossils resembling any sort of copper ore are found in such a vein. It commonly happens, that some little verdigrease or a fine green rust or efflorescence, appears upon the face of copper ore exposed to the external air in the surface of veins, and likewise upon the outside or surface of loose masses of copper ore, which have long been exposed upon the surface of the earth: However, if no verdigrease or such fine green rust should appear, the various colours and appearances of
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the copper ores have been so particularly described as to point them out to an attentive observer, independent of the verdigrease, which, however, is always an indication of the presence of copper in less or greater quantities.

Copper ore may be and often is found upon the surface of the earth in shoals and floats, in the same manner as lead ore, and, therefore, when vein-stones, spars, &c. are found scattered upon the surface, they should be carefully examined, to see if they contain any copper in specks or flowers, and the place should be well examined for less or greater samples of copper ore.

Masses and small bits of copper ore which have slid, or been any way forced off the basket of a vein, and lie scattered upon the surface of the ground, generally show some little verdigrease, and when they do not, the ore has much the same appearance as described above, only a little more dull and tarnished than samples of the same ore newly broken, but the tarnishing is only upon the outside of the masses; but however dull and tarnished such masses and small bits of ore may appear, they have generally a mineral appearance and character, which distinguishes them to an observing eye from common stones; and, therefore, when spar, vein-stone, &c. are seen, every hard substance in such a place should be broken to see how they appear in the inside.

When

When treating of lead ore, I directed how to search for and trace out the veins, by means of ore and other mineral substances found upon the surface, to which I refer, as it need not be repeated here, all circumstances being alike, respecting the shoads or appearances of copper and lead.

Copper ore is found in all the descriptions of soft mineral veins, in the same manner as lead ore, and the copper is accompanied in these veins by most of the soft mineral soils which accompany lead, excepting the white friable clay, which seems peculiar to lead. But of all the soft mineral soils found in veins, the blackish and all the shades of brown chun, or mother, is the most promising for copper. It has been noted before, that chun, which is also called ghurr, is a soft, lax, friable soil, found in the concavities of mineral veins, which generally has a dusty or snuffy appearance when the vein is dry.

When a vein is found, and opened a little, containing this sort of soft soil, if no lead is found in it, then it ought to be carefully examined for copper. Let every hard substance found in the vein, whether it is mixed and buried in the softness, or adhering to the sides, from the size of a small pea, and upwards, be broken, to see if any copper appears, which in such veins is commonly so tarnished or covered over with the soft soil, in which it is buried, as to conceal its real

colour and metallic appearance, which, however, will be discovered when either small or great masses containing copper are broken. But if no masses of good copper are found, nor any specks or threads of copper are discovered in breaking the hard substances of the vein, then let some of the chun be put in a glass with aquafortis, and after standing a little, touch the liquid with clear iron, and if any copper appears, it may be concluded that it is a copper vein, and farther trials should be made by sinking down in it, even to a considerable depth, there being little doubt of finding much copper in such a vein, if you go far enough down in it.

Besides the several descriptions of mineral veins, copper ore is found in all other situations and circumstances the same as lead; such, for instance, as blended in the composition of the strata of lime-stone and other rocks, in the same manner as lead ore, which has been described above, and need not be repeated here.

Copper mines have been worked for a long time in many parts of England, to the great emolument of the public, and of the several districts where this metal is found; but mines of copper have not hitherto made any figure in Scotland. The trials for that metal have neither been numerous nor very successful, perhaps for want of skill and perseverance. But, however
that

that may be, as it is probable that more attention will be paid to that metal hereafter in this country, I will point out some places where I have seen copper ore, and appearances of good copper mines in Scotland, which communication may be useful to posterity.

A great many mineral veins appear in the cliffs of the sea, all round the coast of Caithness, in the north of Scotland, in some of which I have seen lead, and in others copper ore.

Many of those veins are coved by the waves of the sea washing out the softer mineral soils. There are several fine regular rake veins trending towards the north and south, and others towards an east and west direction, near the old ruinous castle of Olrick in Caithness, which intersect one another at right angles, in some of which I found pretty good copper ore.

The veins at Olrick are remarkably good and promising, and regularly open between the sides, containing some copper ore even at the surface, with various other good mineral soils both hard and soft. I just touched the surface of two of the north and south veins at Olrick, which could not be called a trial. One of the places was in the cliff of the sea, about half way down from the summit, in a strong bold vein, containing some copper ore; but as most of the mineral soils in this vein were hard, there was but
very

very little done in it. The other vein was also seen in the cliff, but it was searched for and found by a little trench upon the plain ground above, at some distance from the face of the cliff. This vein was found open and good, immediately below the upper foil, containing spar and vein-stone, and a blackish brown chun, or soft mineral soil, with some copper ore at the very surface; and if I remember well, there was not above a yard sunk down in the vein, just to see how it appeared.

The copper was found in small masses in the chun, and mixed or blended through all the vein-stones and spar. The copper ore at Orlrick was mostly of a yellow and a brown colour, and frequently a mixture of yellow, brown, and green. It did not appear to be very rich in quality; but, perhaps, that is not ultimately against it, for it may be remarked, that in Cornwall, and other places where they have the most rich and durable copper mines, the ore is generally poor in quality, which defect is compensated by the great quantity produced; and as far as I can judge from appearances, Orlrick promises to be a productive copper mine, when the best veins shall be opened and effectually explored.

The best copper ore that I ever saw, and, perhaps, the best that has been seen in Britain, is found at Kissern in the West Highlands of Scotland.

land. This remarkably rich ore is of a reddish grey colour. It is uncommonly ponderous for copper ore, and the best masses of it are sonorous, and ring like the melted metal. This fine ore is found in a rake vein or perpendicular mineral fissure, which crosses a middle-sized hill of fine limestone, within a mile of the sea, or an inlet called Loch-Kissern, upon the west coast of Rossshire. There have been superficial trials made at Kissern, (the name is founded Kishon), and some tons of copper raised at different periods. The ore is found there in nests or small openings in the vein, with short intervals between them, but they have never yet sunk to any depth in it. I am of opinion that Kissern deserves to be explored more effectually by proper trials. There is the highest chance in its favour, not only of this vein and other perpendicular fissures opening wider and more regularly at proper depths, and producing good bodies of ore, but there is also a probability of discovering dilated veins as they work down in the rake veins.

Flat dilated veins are commonly found in all limestone mining fields, and they would probably be met with at Kissern, were the perpendicular veins worked deep enough to come at them. When I was at Kissern, I saw the basset of a flat vein there in the limestone measures, containing iron ore at the surface, a common circumstance
in

in other copper mines. The rake vein, out of which the copper was raised, opens and closes, or checks again, at short intervals near the surface, and they have not gone far down in it. The ore was found in every small opening of the vein, and the quantity found was always in proportion to the size and length of the open space in the vein, and when these openings closed or checked as they worked forward horizontally in the vein, the copper was cut out and lost, until they came to another opening, which was commonly at the end of two or three feet, or of two or three yards at most, when they were sure to find more copper. A shaft put down in the vein where the best and most copper was found, to the depth of twenty or twenty-five fathoms, and a horizontal mine driven likewise in the vein from the bottom of the shaft, a considerable number of fathoms towards the height of the hill, might be productive of great discoveries ; at any event, the copper which would be raised in going down and driving in the vein, would probably defray the expence of the operation. This may be done at a moderate expence, with a small horse-gin or whimsey, instead of a windlass, for drawing the water and work in sinking.

Among the prodigious number of lead veins which are seen in the island of Isla, there are some few regular good veins containing copper ore,
upon

upon which trials to a small depth have been made, and several tons of pretty good copper ore were raised out of them. The copper of Isla is mostly of the yellow, brown, and green colours mixed together, and of a close grain or texture ; but most of the copper of Isla is mixed with blue lead ore, which is a great detriment to the copper.

The Ochill Hills are famous for producing various kinds of good metallic and semi-metallic ores in several places, such as silver, lead, cobalt, &c. and among the rest copper ore has been found in several parts of those mountains, some of which I have not seen ; but I saw some very good regular perpendicular veins bearing copper ore, near the bridge of Allan, which have been worked, and a great deal of copper raised at different periods. The copper of this mining field is good in quality. I do not distinctly remember all the colours of it, but I recollect there was yellow, green, and grey ore produced ; and the yellow copper ore there, which is of a laminated structure, and a bright yellow colour, was the finest yellow copper I ever saw. From my own observations, joined with the information of sensible skilful miners, I am of opinion, that the copper mines at the Bridge of Allan were rashly thrown up and stopped about twenty years ago, when they had good copper in several foreheads, and still better

better in some of their soles, as I thought in sufficient quantity to be worked with profit. But there being no furnaces and other apparatus for preparing and smelting the metal in Scotland, is a great detriment to the success of copper mines in this country.

The mining field at the Bridge of Allan promises a rich and plentiful produce of copper, if conducted with skill, spirit, and frugality.

There have been trials made, and grey, yellow, and greenish brown copper ores found at Curry, in the county of Edinburgh. The grey copper found at Curry was exceeding rich, of a bright grey colour, of a granulated texture, remarkably heavy, and very pure, and from its appearance I imagine it contained some silver. This fine ore was found in limestone, but I do not now remember whether the copper was found in a regular vein, or in nests in the lime-rock. I also saw at Curry a great many small vagrant strings of copper scattered in the superficies of the rock in several places, upon which they have been digging and making superficial trials at different periods. I imagine that they have paid too much attention to those vague appearances, because they saw some little copper, and neglected some real mineral veins, because they did not carry ore immediately at the surface.

There

There are appearances of other copper mines in several parts of Scotland, which I have not seen ; and some that I have seen I do not so distinctly remember as to be able to give a just account of them.

In the parish of Colvend, in Galloway, there are great numbers of mineral veins, in which several species and varieties of copper ores have been found. Many of these veins appear in the rocky cliffs of the sea, upon the north side of the Solway frith, which are high and precipitous. Several of the perpendicular veins containing copper in this field are so narrow and close at the surface of the ground, upon the summit of the rocky cliffs, that they could hardly be known above for mineral fissures, if they were not seen to open gradually wider and wider as they cut the strata asunder down the face of the cliff ; but notwithstanding their being so very strait and close above, many of them open asunder to three or four feet wide, and more, before they are half way down from the summit to the beach, and some of them are six or eight feet wide below at the beach. Some of these veins are coved a considerable way into the hill, by the continual agitation and beating of the waves which washes or gradually wears the mineral foil out of the veins. Many wonderful stories were related to me concerning one of these, called the

Piper's Cove, when I was in that country near thirty years ago, which raised my curiosity to examine it with lights. Before I entered the cove, I saw that it was a large strong mineral vein, which engaged my attention to the internal parts of it as such, and before I came out, I discovered copper ore in the vein.

This prompted me to take a view of the cliffs further along shore, to see if any more discoveries could be made ; and the result of my search was, that I found some copper in the cliffs along shore in more than twenty veins. In a year or two after the first discovery, a company tried several of those veins, and some tons of copper were raised and sold ; but whether the company and their servants had not sufficient skill in copper mines, or that they made some superficial trials in too many places where a little copper appeared, but did not push far enough into the best veins with sufficient spirit and perseverance, or that the ore was found in too small quantity to be worked with profit, or whatever was the cause, the work was thrown up, after making a great number of trifling superficial trials, although some copper was found in most of them. From what I saw and know of the matter, as I sometimes passed that way, my opinion is, that they tried too many places which deserved no trial at all, and of consequence, they soon found too much money out,
and

and but little coming in, which discouraged them; whereas, had they concerted and steadily followed a proper plan, and pushed their trials effectually in two or three of the most promising veins containing copper ore, it is highly probable that their success had been quite different, and that this had proved one of the greatest and best copper mines in Europe. Most of these veins are very close and strait above at the surface of the ground, but open gradually downwards, and several of them are wide and regular below, containing some copper ore at or near the day, with very promising mineral soils, both hard and soft, as brown chun, &c.

A great variety of copper ores appear in this extensive mining field. The principal species are the yellow, green, and brown. There are a great variety of mixtures of the yellow, green, and blue colours, some of which are tinged with all the beauties of the rainbow and peacock's tail; but these gaudy ores are generally in hard poor veins, which do not promise much success, at least not near the surface. In the opener veins, containing soft mineral soils and kindly spar, &c. the yellow ore mixed with green and brown colours are generally prevalent. There were ribs of solid ore in some of these veins, when the trials were given up, in one or two of the best veins the

the rib was up to four or five inches, or more, of a brownish yellow copper, mixed with green; and I am persuaded that the ore in some of those veins would pay for working, as it now stands, if managed with spirit, skill, and frugality; and as the veins are good, and trend into a range of mountains, which have a gradual rise or acclivity from the shore, until they ascend to a great height, there is the greatest probability of success, by driving horizontal mines or galleries in the veins from the shore, towards the mountains, in which veins there is middling good ore to begin upon, which would pay for the mine or gallery; and as most or all of these veins open gradually downwards, it might be prudent to sink down below the level of the sea in one or more of the veins which produce the best ore and other mineral soils.

In short, this is a noble mining field for an able, skilful, prudent company to engage in, and I am persuaded that some time or other, when the best veins shall be properly opened and pursued, this will prove one of the best and most extensive copper mining fields, in Britain, if not in all Europe.

The next metallic ore I shall take notice of is iron. In these cursory observations, concerning the metallic and mineral ores, I follow no system of mineralogy, nor established rule of precedence, but

but I rather have respect to the extent and riches of our British mines, and their importance to our manufactures and commerce, than to any other motive of choice and order. Our lead and copper mines have long been, and still are worked to great extent and advantage, and it is yet very practicable to increase them. Our iron mines and iron furnaces have begun to make a figure of late years, and I hope they will increase in some proportion to their great national consequence.

Of all the mineral ores found in the superficies of the globe, iron is of the greatest importance for all the purposes of society ; and therefore, it should be reckoned the most precious, as it is the most useful of all metals. Iron is either necessary or applicable to most of the great and important uses of metal. Its ferruginous quality is indeed against it for several domestic and ornamental purposes ; but where the great and necessary uses of metal are wanted, for strength, durability, fine edge and point, iron is, without comparison, the most useful and the most valuable metal in the world ; and like the other common bounties of nature, the general abundance of iron is equal to its great utility. However, the other metals have also their value and importance in various ornamental and useful purposes of life, and they are of great consequence to our British manufactures and commerce. Unless it is the
first

first great expence which is requisite for erecting iron works, I am at a loss for the reason why we have so few bloomeries in the island of Britain ; and why we were so long, in Scotland especially, before we began to extend this valuable manufacture of our own produce, which is of such vast national importance.

It is said that a million of good hard cash is annually carried out of the nation for iron, which goes into the coffers of cold friends and commercial enemies. It should be the fervent wish of all the real friends of our national prosperity, that the bloomeries, or iron works of Britain, were so much increased as at least to keep our dry cash at home, and if we imported any iron at all, that it should be in exchange for British manufactures ; and I am persuaded that the means of such an increase is abundant.

Iron works in Scotland, for manufacturing the produce of the country, are but of very late establishment ; but to my certain knowledge, the fossil means of numerous iron works in this country are abundant and good.

I will not pretend to reason upon the policy of national bounties to encourage the increase of these public works ; but it appears to me abundantly evident, that bounties and premiums, wisely disposed of in this way, would prove a national

tional advantage, by employing a great additional number of hands in preparing and manufacturing the produce of our iron mines, and in keeping at home a million of cash annually, which may be employed in carrying on those iron works, by which means it would flow like vital nourishment in home circulation.

Our worthy young Premier has investigated many important subjects respecting our national prosperity,—I wish he would look into this also.

Iron, in its crude fossil state, may be ranked in two sorts, viz. iron ore and iron stone. Iron ore, properly so called, is found in all the several species of mineral veins described above, and also upon the surface of the earth, in a coagulated or concreted state, which is called bog-ore, and iron stone is found in thin but regular strata in the coal fields and others, and in glebes and nodules of various sizes, blended in argillaceous strata likewise of the coal fields. Several species of iron-stone, such as ruddle and slaty or shivery iron-stone or ore, are found in regular continuous strata among the strata of the mountain rocks, and it is found in indurated rocks in many places.

There are several species of iron ore, such as,
 1st, *Blood-stone* ; 2^d, *Kidney ore* ; 3^d, *Grey iron ore* ;

ore ; 4th, *Bog ore*, &c. and of each of these there are many varieties.

1st, The *hæmatites*, or *blood-stones*, are reckoned among the richest of the iron ores. They are either of a dark brown, a reddish brown, or of a grey colour, remarkably heavy, and generally of a radiated structure. The reddish and brown sorts are commonly of a smooth uniform texture ; but the grey are frequently granulated, some of which are of a dark grey colour and dull appearance, and other varieties are of a light grey and of a bright metallic appearance.

The masses of these sorts are strongly marked, being of a striated and radiated form and texture ; the radii very distinct, and diverging every way from a common center, and they are generally mixed with a whitish or flesh-coloured iron spar. Many varieties of the blood-stones are very hard, as well as the iron spar which accompanies them.

2d, *Kidney ore* is found in small masses blended in a red, staining, soft clay or earth, called *smut*, which is also an iron ore. The solid masses which are mixed in this red clay are remarkably heavy, and of a blackish brown, or dark grey colour ; they are either roundish or kidney shaped, and of a crustated structure, the small masses being formed of concentric crusts or folds like an onion, though in some varieties the small masses

ses of ore are of a more solid structure, without the appearance of different folds or crusts. The most profitable iron mines in Britain produce this species of ore.

2d, Grey iron ore, of which there are many varieties, most of them pretty hard and heavy, and sometimes of a dull blue, but generally of various shades of an iron grey colour. Some varieties of the grey iron ores are of a granulated texture, and composed, some of coarse grains, resembling coarse iron when broken, and others of finer grains, resembling the steel-grained lead ores; and some of these are of a blackish or dark grey, and others of a bright grey colour, resembling some of the granulated lead ores. Again, some varieties of the grey ores are of a cubical or diced structure, and others are scaly, and these are composed of larger and smaller cubes, and of larger and smaller scales, in the same manner as the diced and scaly lead ores, which many of these resemble, only that they are of a duller blue, or of an iron grey colour.

But I will not pursue this description, which is not very necessary, the iron ores in general being pretty easily known and distinguished from all others, by their being accompanied with less or more of a brownish red, or of a brighter red soft soil, which indelibly stains the hands and cloaths, and therefore I will leave the description imper-

fect, and will proceed to point out some of the many places in Scotland where I have seen appearances of good iron mines ; and it was only for the sake of communicating this local history, which may be of future use, that I said any thing at all about iron.

I have formerly seen appearances of iron ore in several places round the coasts, from the west side of St Andrews to Montrose ; but it is so long ago, that I can now give no distinct account of the matter.

About seven or eight miles north of Montrose, in the neighbourhood of a fishing town, which I think is called John's-Haven, there are strong appearances of plenty of good iron ore, particularly near Mr Carnegie of Charlton's lime works. The iron among these lime works appears at first sight to be plenty and good, but my stay there was so short that I had no time to examine it minutely. It is easily distinguished by the strong, red, staining softness which accompanies it. If this ore is found good, it is almost close to the sea.

There are appearances of iron ore between those lime-works and Stonehaven, and between Stonehaven and Aberdeen, concerning which I can say nothing distinctly.

There are strong appearances of iron upon the coast, about the Ord of Caithness, and in
many

many places between the Ord and Wick, and to the northward of Wick.

The coast of Caithness is remarkable for pretty high rocky cliffs, in which great numbers of veins, or perpendicular mineral fissures appear, many of which contain iron ore. I remember observing some of these near the old ruinous castle of Girnigo, and between Girnigo and the castle of Ackergill. These veins appeared to be bold and roomy, and to contain plenty of good iron ore, from the abundance of a bright red iron earth found in the surface of them; but I did not thoroughly examine circumstances, having no prospect then that iron ore would so soon become of consequence in Scotland.

There is great abundance of bog ore over all the low country of Caithness. In many places it almost covers the whole face of the ground to a considerable depth. It is easily known and distinguished by the friable constitution of its misshapen masses; by its blackish and rusty colour on the outside, and by its blackish grey colour and granulated porous texture in the inside. It is always found loose upon the surface of the ground, in the same manner as float ore, without any connection with vein or stratum.

Iron ore has been wrought in the main island of Orkney, and shipped for use at Carron, concerning

cerning which I can say nothing farther, as I never saw it.

Good iron ore appears in the lime rocks of Kissern in Rossshire, where the rich copper mentioned above was found. I did not traverse all the lime rocks at Kissern, but I saw fine iron there in two different places, and of two different species. The first which I observed is grey iron ore, contained in a perpendicular fissure or rake vein, which appears distinctly in the side of a small rivulet near the road, upon the south side of the field in which the copper was found. This vein, if I remember well, is between two and three feet wide at the surface, and full of good-like grey iron ore. In the second place which I observed, the iron seems to be of the species called kidney ore, and it is contained in a flat or dilated vein in the lime-stone, and situated about a hundred yards or more westward from the copper vein. I saw not the least trial upon either of these two, but they appear to be very good. The site of them and of the copper is about a mile from the sea, or salt-water loch of Kissern.

I am persuaded that several of the Western Isles abound in iron ore, some of which I have seen in Cannay, &c. which I had not time to examine.

There

There appears plenty of good iron ore in several mineral veins in the south side of the mining island of Ila, part of which is found in the lime within the bounds of the lead mining field, and part to the south of the field which abounds most in lead ore. There are many appearances of iron along the coast of Ila, which I have only seen at a distance, but from what came under my eye, I am confident that Ila is an eligible place to search for a valuable iron mine, which would answer well for iron works upon the Clyde, in Ayrshire, or in any part of the west coast.

A strong appearance of a great quantity of iron is to be seen in the hills which are situated to the eastward of Girvan in Ayrshire, which appearance of iron stretches away longitudinally towards the north-east, as far as the parishes of New Cumnock and Muirkirk, which may be soon of great use to the new iron works lately erected at Muirkirk, and perhaps to others in the course of time, there being plenty of coal and coal-field iron-stone in the south-east parts of Ayrshire.

Iron mines appear in many places upon the sea coast of Galloway, particularly in the parish of Colvend, both to the west and east of the copper mining field above-mentioned, where many veins containing kidney ore and other species are to be found,

found, several of which I have seen, but not examined.

The north-west side of the Ochil hills abounds in iron, which I have seen in crossing those hills. It stretches longitudinally, but of what quality I do not know; however, it deserves to be ascertained, the site being convenient for the great quantities of excellent coal and iron-stone of the coal-field found upon the banks of the Devan, a plentiful stream, and in the moors to the south of the Devan.

The iron ore or iron-stone at Noblehouse is pretty well known, being opened a little a few years ago by the proprietor, Sir William Montgomery of Magbyhill. This is not a vein, but a stratum of iron, which stretches longitudinally a considerable way towards the north-east and south-west, through the lands of Magbyhill, La Mancha, and others. This stratum of iron is of considerable thickness, being above twenty feet across the stratum where it was opened at the surface near Noblehouse. It is a slaty or shivery iron ore, or iron stone, of a reddish brown colour, and smooth uniform texture in the inside of the masses when broken, and mixed with staining iron earth of the same colour. When I saw this iron mine, I thought the ore should have been very rich, but was told that it only produced about twenty-five or thirty per cent.

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at most upon trial ; however, as they only dig the surface of the stratum, which must be mixed with surface-earth carried down by rains into the iron ore for ages, I imagine it should be richer if worked down to a proper depth. I am persuaded that this will become of great value in the course of time, as the extensive muirs to the north of it abound in coal and coal-field iron-stone, and the situation only sixteen miles from Edinburgh, and convenient for the extensive inland countries to the south and west of it.

The best of all iron-stone, which is found in thin strata, and also in detached glebes and nodules in the argillaceous strata which accompany seams of coal, abounds in all parts of Scotland where any strata of coal have been discovered. I call this iron-stone of the coal-field, because it is always found in those argillaceous strata which attend coal, and which are very commonly the immediate roof of coal ; and therefore, it is customary to rummage the coal wastes for this sort of iron-stone, from whence it is raised much cheaper than by digging it out of solid ground.

This species of iron-stone is found upon both sides of the frith of Forth, from the east of Fife and opposite, all the way up to Stirling, a length of more than fifty miles, and in a great many places it is found quite down to the shore, and within flood-mark. Upon the north side of
the

the Forth, the coal-field, and of course the iron-stone field is generally about eight miles broad from the shore inland, and in length, as hinted before, above fifty miles. The iron-stone in this extensive coal-field is very plenty and very good, and it is all entire, excepting a very little, which the Carron Company have picked near the shore, and a considerable quantity which they have taken from Pitfirran.

The inland coals at a distance from the shore are remarkably good and plenty in several parts of Fife and Clackmannan shires, and as there is appearance of iron ore in the Ochil hills, this country may, in the course of time, become the site of extensive and valuable iron works.

The iron-stone upon the south side of the Forth is found as abundant and as good as upon the north side, with this addition, that in many places the coal and iron-stone field upon the south side is more than double the breadth of the other. The greatest part of this south field reaches from the banks of the Forth all the way to the south side of Ayrshire, which is more than six times the breadth of that upon the Fife side of the water.

The Mid-Lothian coal and iron-stone field reaches from the south shore of the Forth near twenty miles up the country towards the south-west, and it is of pretty equal breadth, being every

every where about twelve or thirteen miles across. The south-east side of this field consists of a range of horizontal strata, and the north-west side of vertical or greatly sloping strata, and both ranges abound in good coals and iron-stone. The flat, broad, or horizontal coals of this great field are of excellent quality, and remarkably plenty and cheap in the neighbourhoods of Ormiston, Cranston, Carrington, and Temple, which districts also abound in good iron-stone ; and therefore, these are supposed to be good situations for iron works ; and iron ore is found in abundance at Noblehouse, and farther east ; and there is appearance of iron ore in the range of hills upon the south side of this coal-field.

In the range of vertical and greatly sloping strata, in the north-west side of the Mid-Lothian coal-field, there are a great number of thick seams of excellent coal, and the strata of iron-stone are innumerable, besides a great quantity of nodules contained in thick beds of coal-till, and all apparently of excellent quality. The coals of this range, for eight or ten miles from the shore, sell at a good price, being carried to Edinburgh ; but farther up the country they are of small value, and not worked at all, or none to signify ; and, therefore, it is presumed, that the neighbourhoods of Auchindinny, Pennycuick, and Newhall, would be eligible situations for iron

works, which can be supplied with excellent and cheap coals from the horizontal strata upon the south, and from the edge seams upon the north side of the river Esk, and with abundance of iron-stone from both, part of which can be carted westward from the coal wastes of Loanhead and Gilmerton; and there is abundance of iron ore for mixing with the stone at Noblehouse, and farther east, at a small distance from these proposed iron works.

It should give real pleasure to all the friends of our national prosperity to observe, that iron works have been lately erected at Cleugh, upon the banks of the river Clyde above Glasgow, and at Muirkirk, which I heartily wish may succeed. Other proper inland situations in the counties of Lanark, Renfrew, and Ayr, where coals are plenty, excellent, and of small value, and the iron-stone plenty and good, are so numerous, that I will not attempt to point them out. I wish that plenty of good iron ore were to be found contiguous to these situations. But I have already said as much upon this subject as is consistent with brevity, propriety, and truth.

THE END OF VOLUME I.

ERRATA in this VOLUME.

In the PREFACE.

Page 21. line 11. *after the word and, read I hope to.*

25. l. 19. *for for, read if.*

V O L. 1.

P. 3. l. 15. *for of working, read and working.*

19. l. 4. *for aright, read right.*

24. l. 23. *for are, read is.*

28. l. 6. *for is, read are.*

39. l. 3. *for strata of ball, read strata and ball.*

146. l. 10. *read composed altogether of the same strata of coal metals.*

186. l. 15. *read sufficient to stimulate them to.*

191. l. 3. *for unreasonable, read unseasonable.*

226. l. 26. *for discomposed, read decomposed.*

249. l. 1. *for cake, read cokes.*

299. l. 12. *for they, read the soft soils.*

309. l. 6. *for latch holes, read loch holes.*

311. l. 11. *for washing, read rushing.*

317. l. 16. *for figures, read fissures.*

361. l. 17. *for round, read rounded.*

364. l. 17. *this mark | should be thus +.*

365. l. 18. *for whinstone, read veinstone.*

366. l. 16. *for basing, read baring.*

371. l. 16. *for worked, read marked.*

395. l. 26. *for sacred, read sound.*

403. l. 8. *for perpendicular, read particular.*

427. and 428. *for Olrick, read Old Wick.*

441. l. 5. *for 2d, read 3d.*